〔7〕 Permeability Tests Applied to Ene River Project.

Appendix A-2[7] Permeability Tests Applied to Ene River Project

The permeability tests described below were performed at all drillholes in the project area.

"Le Franc" type permeability tests were adopted for parts where there were riverbed deposits and "Lugeon" type for bedrock parts.

(1) Permeability Tests of "Le Franc" Type

The "Constant Load Method" was applied to the parts of riverbed deposits with comparatively high permeability and the "Variable Load Method" to the parts of comparatively low permeability.

Coefficients of permeability (K_1) and (K_2) were calculated by Eqs. (1) and (2) using values obtained by the "Constant Load Method."

$$(K_1) = \frac{qi}{C_1 \times hi} \quad \cdots\cdots (1)$$

$$(K_2) = \frac{qi}{C_2 \times hi} \quad \cdots\cdots (2)$$

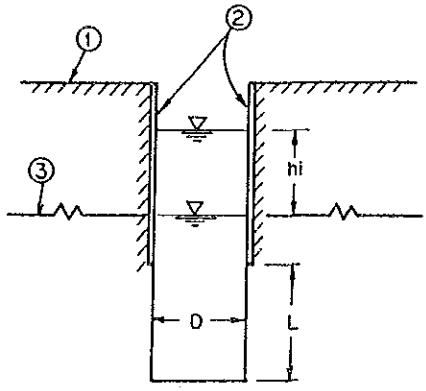


DIAGRAM: Permeability Test in Drillhole

① Ground surface
② Casing pipe of hole
③ Ground water table

Where,

C_1 ; Coefficient given by Formura (3)

$$C_1 = \frac{2\pi L}{\mathrm{Ln}(2L/D)} \quad \cdots\cdots (3)$$

C_2 ; Coefficient given by Formura (4) or (5) or (6) or (7)

At, $L/D = 0$ $\quad C_2 = 2D \quad \cdots\cdots (4)$

$$0 < L/D < 1, \quad C_2 = 2\pi D\sqrt{L/D + 1/4} \quad \cdots\cdots (5)$$

$$1 < L/D < 4, \quad C_2 = \frac{2\pi L}{\mathrm{Ln}(LD + L2/D2 + 1)1/2} \quad \cdots\cdots (6)$$

$$L/D < 4, \qquad C_2 = \frac{2\pi L}{Ln(2L/D)} \quad \cdots\cdots (7)$$

L : Length of section tested
D ; Diameter of drillhole
hi; Hydraulic head of injection
qi; Injected water volume per unit time

Coefficient of permeability (K_3') was calculated by Eq. (8) using values obtained by the "Variable Load Method".

$$(K_3') = \frac{\pi D^2}{4C_2(t2 - t1)} \log_e \frac{h2}{h1} \quad \cdots\cdots (8)$$

Where,

h1 ; hydraulic head at t1
h2 ; hydraulic head at t2
t1 ; time of starting injection
t2 ; time of finishing injection
D ; diameter of drillhole
C_2 ; coefficient given by Eq. (4) or (5) or (6) or (7)

(2) Permeability Tests of "Lugeon" Type

"Lugeon" type permeability tests were applied to the parts of bedock in drillholes. Coefficient of permeability (K_3) was calculated by Eq. (9) using values obtained by "Lugeon" tests.
Δ t 2L/D >> 1,

$$(K_3) = \frac{qi}{2\pi Lhi} \cdot Ln\ (2L/D) \quad \cdots\cdots (9)$$

Where,

L; length of section tested
D; diameter of drillhole
h1; hydraulic head of injection
qi; injected water volume per unit time

[8] List of Permeability Tests

LISTS OF PERMEABILITY TESTS

DRILLHOLE DT-1 LE FRANC PERMEABILITY TESTS

Test N°	Depth mts.	L mts.	Constant Load		
			Hi cm	K1 cm/sec.	K2 cm/sec.
1	5.00	00	115	3.64×10^{-2}	
			65	3.25×10^{-2}	1.90×10^{-2}
			00	2.26×10^{-2}	
2	15.00	00	70	3.28×10^{-2}	
			35	3.50×10^{-2}	3.78×10^{-2}
			00	3.58×10^{-2}	
3	25.00	00	75	3.51×10^{-2}	
			45	3.79×10^{-2}	4.53×10^{-2}
			00	4.10×10^{-2}	

DRILLHOLE DT-2 LE FRANC PERMEABILITY TESTS

Test N°	Depth mts.	L mts.	Constant Load		
			Hi cm	K1 cm/sec.	K2 cm/sec.
1	12.50-15.00	2.50	00	4.27×10^{-3}	
2	20.85-25.00	4.15	150	4.33×10^{-3}	
			100	5.18×10^{-3}	3.81×10^{-3}
			00	3.95×10^{-3}	
3	25.15-30.00	4.85	00	4.12×10^{-3}	
			75	4.42×10^{-3}	4.09×10^{-3}
			160	6.15×10^{-3}	

LISTS OF PERMEABILITY TESTS

DRILLHOLE DT-2

LUGEON PERMEABILITY TESTS

Test N°	Depth mts.	Po kg/cm^2	P kg/cm^2	Lugeon	K_3 cm/sec.
1	25.00 - 30.00	0	0.230	1.165	1.321×10^{-2}
2	32.00 - 35.00	1	1.23	238.482	2.788×10^{-3}
		2	2.23	171.151	2.001×10^{-3}
		1	1.23	227.100	2.655×10^{-3}
3	36.70 - 40.00	1	1.222	217.478	2.597×10^{-3}
		1.6	1.822	183.448	2.191×10^{-3}
		1	1.222	228.389	2.728×10^{-3}
4	42.50 - 45.00	1	1.223	388.553	4.354×10^{-3}
5	46.50 - 50.00	1	1.205	265.797	3.216×10^{-3}
		1.6	1.805	220.024	2.662×10^{-3}
		1	1.205	264.375	3.199×10^{-3}

DRILLHOLE DT-3

LE FRANC PERMEABILITY TESTS

Test N°	Depth mts.	L mts.	Constant Load			Variable Load
			Hi cm	K_1 cm/sec.	K_2 cm/sec.	K_3'cm/sec.
1	8.86 - 9.45	0.59	-	-	-	$4.13 - 10^{-5}$
2	12.80	00	00	1.44×10^{-2}	-	-
			100	1.45×10^{-2}	1.23×10^{-2}	-
			200	2.43×10^{-2}	-	-
3	14.20 -15.05	0.85	-	-	-	1.04×10^{-5}
4	25.00	00	-	-	-	2.40×10^{-5}
5	35.00	00	-	-	-	6.72×10^{-6}
6	39.00 -40.00	1.00	-	-	-	7.74×10^{-6}

LISTS OF PERMEABILITY TESTS

DRILL HOLE DE-1 LUGEON PERMEABILITY TESTS

Test N°	Depth mts.	Po kg/cm^2	p kg/cm^2	Lugeon	K_3 cm /sec.
1	1.95 - 5.10	1	1.362	30.068	3.365×10^{-4}
		2	2.362	84.002	9.401×10^{-4}
		3	3.362	121.432	1.359×10^{-3}
		2	2.362	140.720	1.575×10^{-3}
		1	1.362	171.317	1.917×10^{-3}
2-a	5.00 - 10.00	0.5	1.21	183.471	2.278×10^{-3}
2-b	6.85 - 10.00	0.5	1.21	275.482	3.083×10^{-3}
2-c	7.75 - 10.00	1	1.71	00	00
		3	3.71	00	00
		5	5.71	00	00
		3	3.71	00	00
		1	1.71	00	00
3	11.55 - 15.00	1	1.665	35.340	4.040×10^{-4}
		5	5.665	26.146	2.989×10^{-4}
		10	10.665	22.150	2.532×10^{-4}
		5	5.665	30.955	3.538×10^{-4}
		1	1.665	56.752	6.488×10^{-4}
4	15.00 - 20.00	1	1.674	12.784	1.587×10^{-4}
		5	5.674	11.667	1.449×10^{-4}
		10	10.674	14.521	1.803×10^{-4}
		5	5.674	19.281	2.394×10^{-4}
		1	1.674	31.183	3.872×10^{-4}
5	20.00 - 25.00	1	1.675	00	00
		5	5.675	4.053	5.032×10^{-5}
		10	10.675	3.934	4.885×10^{-5}
		5	5.675	5.075	6.301×10^{-5}
		1	1.675	8.478	1.053×10^{-4}

LISTS OF PERMEABILITY TESTS

DRILL HOLE DE-1 LUGEON PERMEABILITY TESTS

Test N°	Depth mts.	Po kg/cm^2	P kg/cm^2	Lugeon	K3 cm /sec.
6	25.00 - 30.00	1	1.726	37.428	4.882×10^{-4}
		5	5.726	24.135	3.148×10^{-4}
		9.5	10.226	20.595	2.686×10^{-4}
		5	5.726	26.580	3.467×10^{-4}
		1	1.726	40.093	5.230×10^{-4}
7	30.00 - 35.00	1	1.696	8.019	1.046×10^{-4}
		5	5.696	6.285	8.199×10^{-5}
		10	10.696	7.423	9.684×10^{-5}
		5	5.696	7.760	1.012×10^{-4}
		1	1.696	11.439	1.492×10^{-4}
8	35.00 - 40.00	1	1.712	00	00
		5	5.712	1.646	2.147×10^{-5}
		10	10.712	1.643	2.143×10^{-5}
		5	5.712	1.961	2.558×10^{-5}
		1	1.712	2.336	3.048×10^{-5}
9	40.00 - 45.00	1	1.712	00	00
		5	5.712	0.175	2.284×10^{-6}
		10	10.712	0.131	1.705×10^{-6}
		5	5.712	00	00
		1	1.712	00	00
10	45.00 - 50.00	1	1.726	4.751	6.197×10^{-5}
		5	5.726	3.493	4.556×10^{-5}
		10	10.726	2.927	3.819×10^{-5}
		5	5.726	3.388	4.420×10^{-5}
		1	1.726	5.562	7.256×10^{-5}

[9] Records of Permeability Tests

(1) Drillhole DT-1 Records of Permeability Tests

GEOTEC S.A.

PROJECT : TAMBO 10

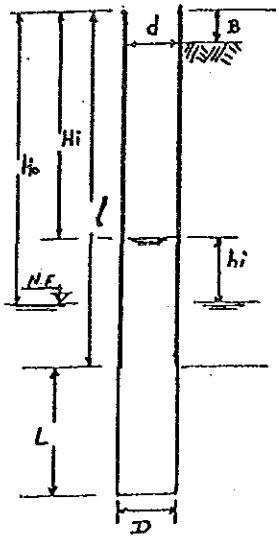
Sheet (1 –34)

SURVEY :

TEST OF LE FRANC PERMEABILITY N°01
(CONSTANT LOAD)

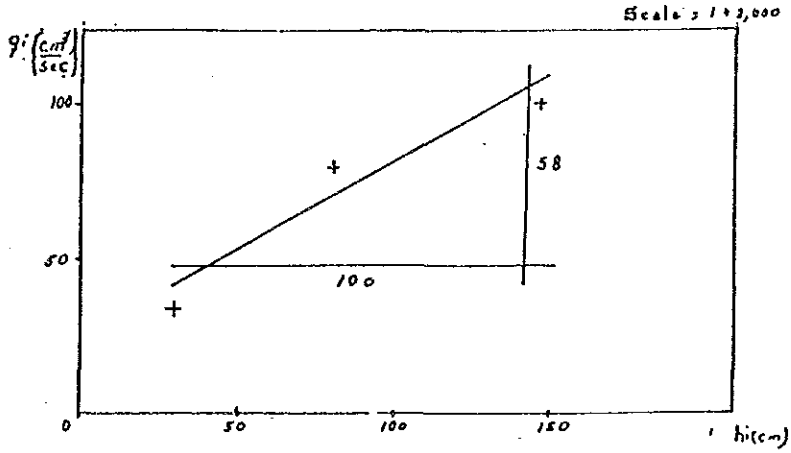
Date : 06-10-84	Driller : J. Cornelio
Boring : DT-1	Performed by : G. Lazo
Depth of Test : 5.00 m.	Revised by :
Phreatic level: 1.20 m	Zone : PUERTO PRADO

DIAGRAM



DATA

D =	10.16 cm	Ho =	145 cm
d =	15.24 cm	B =	25 cm
l =	525 cm	L =	00 cm
T° of boring water :			29°C
T° of river water :			28°C



Hour	Ho (cm)	Hi (cm)	hi (cm)	Vi (cm³)	ti (sec)	qi (cm²/sec)	K1 (cm/sec)
11h30'	145	115	30	2,000	60	33.33	3.64×10^{-2}
12h00'	145	65	80	4,750	60	79.17	3.25×10^{-2}
12h30'	145	00	145	6,000	60	100.00	2.26×10^{-2}

OBSERVATIONS

$K_2 = 1.90 \times 10^{-2}$ cm/sec.

hi : Ho - Hi
qi : Vi / ti
K1 = qi / c hi
K2 = m / c

Where : C = Form coefficient
m = Straight line gradient
K' = Net Permeability coefficient

LE FRANC PERMEABILITY RATE

$$\frac{L}{D} = 0$$

$$c = 2d = 2 \times 15.24$$

$$c = 30.48$$

$$K_1 = \frac{q_i}{c\, h_i}$$

$$K_1 = \frac{33.33}{30.48 \times 30} = 0.03645 = 3.64 \times 10^{-2} \text{ cm/sec.}$$

$$K_1 = \frac{79.17}{30.48 \times 80} = 0.03247 = 3.25 \times 10^{-2} \text{ cm/sec.}$$

$$K_1 = \frac{100.00}{30.48 \times 145} = 0.02263 = 2.26 \times 10^{-2} \text{ cm/sec.}$$

$$m = \frac{q_i}{h_i} = \frac{58}{100} = 0.58$$

$$K_2 = \frac{m}{c} = \frac{0.58}{30.48} = 0.01902$$

$$K_2 = 1.90 \times 10^{-2} \text{ cm/sec.}$$

GEOTEC S.A.

PROJECT : TAMBO 10

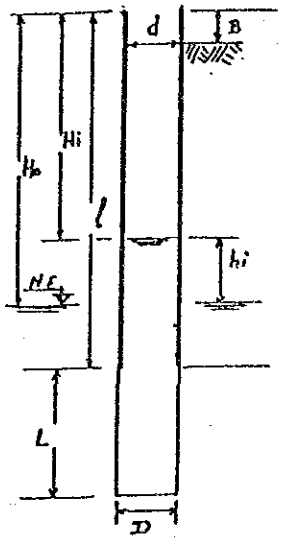
Sheet (3—34)

SURVEY :

TEST OF LE FRANC PERMEABILITY Nº02
(CONSTANT LOAD)

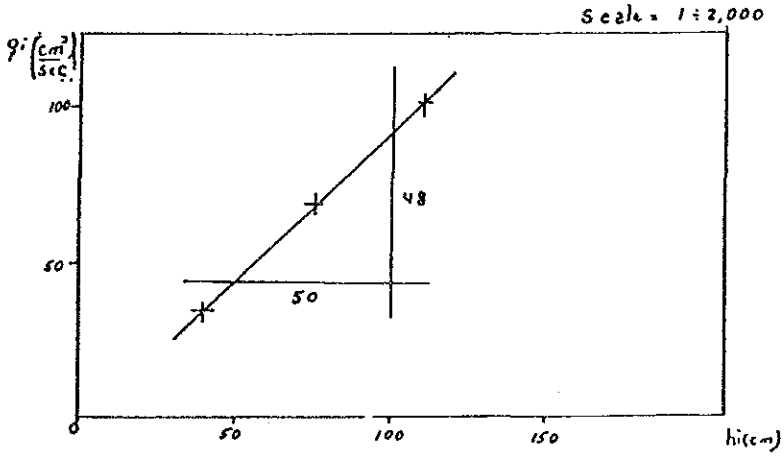
Date	: 16-10-84	Driller	: J. Cornelio
Boring	: OT-1	Performed by	: G. Lazo
Depth of Test	: 15.00 m.	Revised by	:
Phreatic level	: 1.00 m.	Zone	: PUERTO PRADO

DIAGRAM



DATA

D =	9.27 cm	Ho =	110 cm
d =	12.7 cm	B =	10 cm
l =	1510 cm	L =	00 cm
T° of boring water :		29°C	
T° of river water :		28°C	



Hour	Ho (cm)	Hi (cm)	hi (cm)	Vi (cm³)	ti (sec)	qi (cm³/sec)	Ki (cm/sec)
16h 20'	110	70	40	2,000	60	33.33	3.28×10^{-2}
16h 60'	110	35	75	4,000	60	66.67	3.50×10^{-2}
17h 15'	110	00	110	6,000	60	100.00	3.58×10^{-2}

OBSERVATIONS

$K_2 = 3.78 \times 10^{-2}$ cm/sec

hi = Ho - Hi
qi = Vi / ti
K_1 = qi / c hi
K_2 = m / c

Where : C = Form coefficient
m = Straight line gradient
K' = Net Permeability coefficient

LE FRANC PERMEABILITY RATE

$$\frac{L}{D} = 0$$

$$c = 2d = 2 \times 12.7$$

$$c = 25.4$$

$$K_1 = \frac{qi}{chi}$$

$$K_1 = \frac{33.33}{25.4 \times 40} = 0.03280 = 3.28 \times 10^{-2} \text{ cm/sec.}$$

$$K_1 = \frac{66.67}{25.4 \times 75} = 0.03499 = 3.50 \times 10^{-2} \text{ cm/sec}$$

$$K_1 = \frac{100.00}{25.4 \times 110} = 0.03579 = 3.58 \times 10^{-2} \text{ cm/sec}$$

$$m = \frac{qi}{hi} = \frac{48}{50} \qquad m = 0.96$$

$$K_2 = \frac{m}{c} = \frac{0.96}{25.4} = 0.03779$$

$$K_2 = 3.78 \times 10^{-2} \text{ cm/sec.}$$

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PROJECT : TAMBO 50

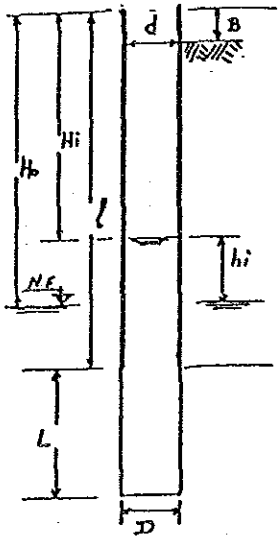
Sheet (5 — 34)

SURVEY :

TEST OF LE FRANC PERMEABILITY N°03
(CONSTANT LOAD)

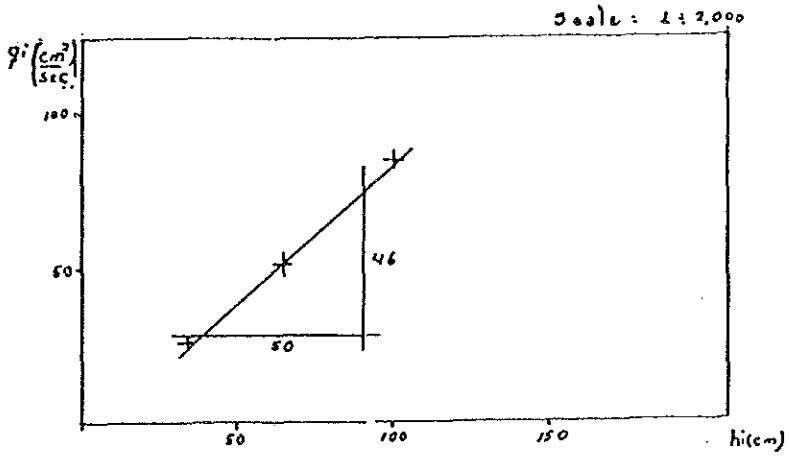
Date : 19-10-84	Driller : J. Cornelio
Boring : DT-1	Performed by : G. Lazo
Depth of Test : 25.00 m	Revised by :
Phreatic level: 0.90 m	Zone : PUERTO PRADO

DIAGRAM



DATA

D =	9.27 cm	Ho =	100 cm
d =	10.16 cm	B =	10 cm
l =	2510 cm	L =	00 cm
T° of boring	water : 28°C		
T° of river	water : 28°C		



Hour	Ho (cm)	Hi (cm)	hi (cm)	Vi (cm³)	ti (sec)	qi (cm³/sec)	K1 (cm/sec)
12h 50'	100	75	35	1,500	60	25.0	3.51×10^{-2}
13h 15'	100	45	65	3,000	60	50.0	3.79×10^{-2}
13h 40'	100	00	100	5,000	60	83.3	4.10×10^{-2}

OBSERVATIONS

K_2 : 4.53×10^{-2} cm/sec.

- $hi = Ho - Hi$
- $qi = Vi / ti$
- $K_1 = qi / c\,hi$
- $K_2 = m / c$
- Where : c : Form coefficient
  m : Straight line gradient
  K' : Net Permeability coefficient

LE FRANC PERMEABILITY RATE

$$\frac{L}{J} = 0$$

$$C = 2d = 2 \times 10.16$$

$$C = 20.32$$

$$K_1 = \frac{q_i}{C h_i}$$

$$K_1 = \frac{25}{20.32 \times 35} = 0.03515 = 3.51 \times 10^{-2} \text{ cm/sec.}$$

$$K_1 = \frac{50}{20.32 \times 65} = 0.03786 = 3.79 \times 10^{-2} \text{ cm/sec}$$

$$K_1 = \frac{83.3}{20.32 \times 100} = 0.04099 = 4.10 \times 10^{-2} \text{ cm/sec}$$

$$m = \frac{q_i}{h_i} = \frac{46}{50} \qquad m = 0.92$$

$$K_2 = \frac{m}{C} = \frac{0.92}{20.32} = 0.045 28$$

$$K_2 = 4.53 \times 10^{-2} \text{ cm/sec.}$$

GEOTEC S.A.

PROJECT : TAMBO 10

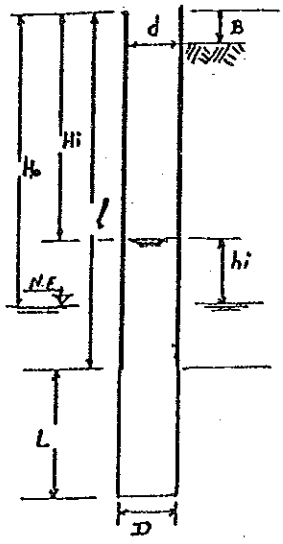
Sheet (7 – 34)

SURVEY :

TEST OF LE FRANC PERMEABILITY N°1
(CONSTANT LOAD)

Date : 22-09-84	Driller : F. VILCA
Boring : DT-2	Performed by : G. LAZO
Depth of Test : 12.5 - 15.00 m.	Revised by :
Phreatic level : 1.50 m.	Zone : PUERTO PRADO

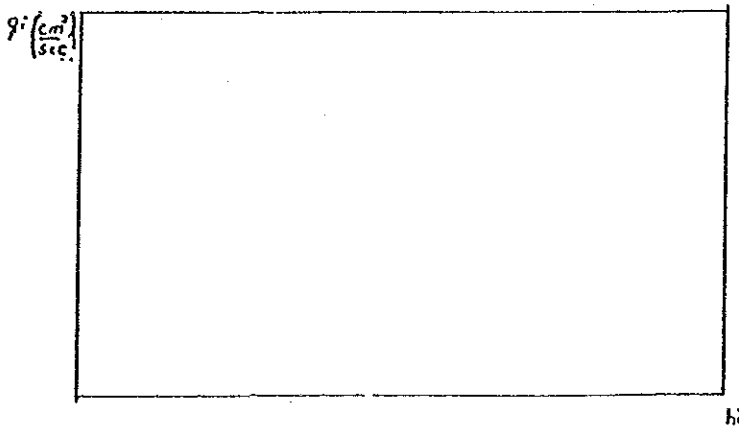
DIAGRAM



DATA

D =	7.315 cm	Ho =	150 cm
d =	7.62 cm	B =	00 cm
l =	1,250 cm	L =	250 cm
T° of boring water :		27°C	
T° of river water :		27°C	

River Level : 2.10 m.



Hour	Ho (cm)	Hi (cm)	hi (cm)	Vi (cm³)	ti (sec)	qi (cm³/sec)	K (cm/sec)
17h10'	150	00	150	14,300	60	238.33	4.27×10^{-3}

OBSERVATIONS

$hi = Ho - Hi$
$qi = Vi / ti$
$K_1 = qi / c\,hi$
$K_2 = m / c$

Where : C = Form coefficient
m = Straight line gradient
K' = Net Permeability coefficient

(2) Drillhole DT- 2

Records of Permeability Tests

LE FRANC PERMEABILITY RATE

$$\frac{L}{D} = \frac{250}{7.315} = 34.17$$

$$C = \frac{2\pi L}{L_w\left(\frac{2L}{D}\right)}$$

$$C = \frac{2\pi 250}{L_w\left(\frac{2 \times 250}{7.315}\right)}$$

$$C = 371.81$$

$$K_i = \frac{q_i}{C h_i}$$

$$K_i = \frac{238.33}{371.81 \times 150}$$

$$K_i = 4.27 \times 10^{-3} \text{ cm/sec.}$$

GEOTEC S.A.

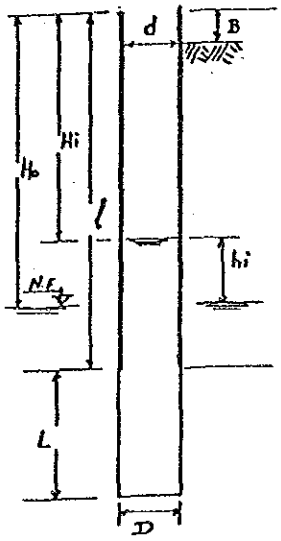
PROJECT : TAMBO 70

SURVEY :

TEST OF LE FRANC PERMEABILITY N°2
(CONSTANT LOAD)

Date : 25-09-84	Driller : F. VILCA
Boring : DT-2	Performed by : G. Lazo
Depth of Test : 20.85 - 25.00m	Revised by :
Phreatic level: 1.80 m.	Zone : PUERTO PRADO

DIAGRAM

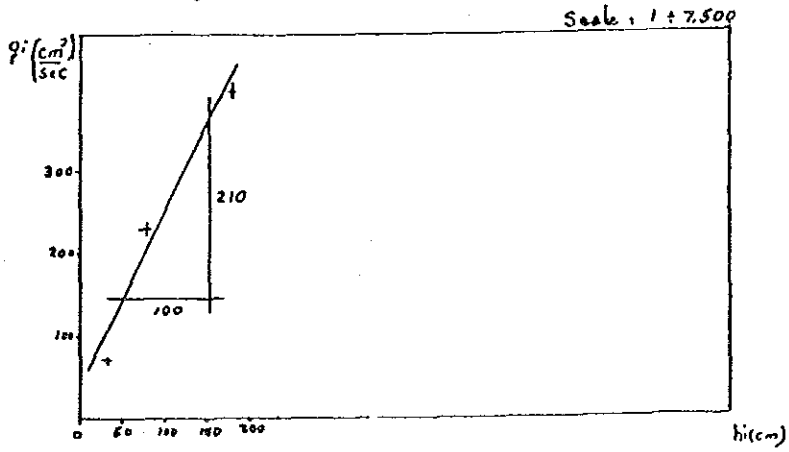


DATA

D =	7.315 cm	Ho =	180 cm
d =	7.62 cm	B =	00 cm
l =	2085 cm	L =	415 cm

T° of boring water : 27°C
T° of river water : 25°C

River Level : 2.05 m.



Hour	Ho (cm)	Hi (cm)	hi (cm)	Vi (cm³)	ti' (sec)	qi (cm²/sec)	K1 (cm/sec)
16h50'	180	150	30	4,300	60	71.67	4.33×10^{-3}
17h20'	180	100	80	13,700	60	228.33	5.18×10^{-3}
17h50'	180	00	180	23,500	60	391.67	3.95×10^{-3}

OBSERVATIONS

$K_2 = 3.81 \times 10^{-3}$ cm/sec.

$hi = Ho - Hi$
$qi = Vi / ti$
$K_1 = qi / C\,hi$
$K_2 = m / C$

Where : C = Form coefficient
m = Straight line gradient
K' = Net Permeability coefficient

LE FRANC PERMEABILITY RATE

$$\frac{L}{D} = \frac{415}{7.315} = 56.73$$

$$C = \frac{2\pi L}{Ln\left(\frac{2L}{D}\right)}$$

$$C = \frac{2\pi\ 415}{Ln\left(\frac{2 \times 415}{7.315}\right)} \qquad C = 551.098$$

$$K_1 = \frac{q_i}{C\ h_i}$$

$$K_1 = \frac{71.67}{551.098 \times 30} = 4.33 \times 10^{-3}\ cm/sec.$$

$$K_1 = \frac{228.33}{551.098 \times 80} = 5.18 \times 10^{-3}\ cm/sec.$$

$$K_1 = \frac{391.67}{551.098 \times 180} = 3.95 \times 10^{-3}\ cm/sec.$$

$$m = \frac{q_i}{h_i} = \frac{210}{100} = 2.10$$

$$K_2 = \frac{m}{C} = \frac{2.10}{551.098}$$

$$K_2 = 3.81 \times 10^{-3}\ cm/sec.$$

GEOTEC S.A.

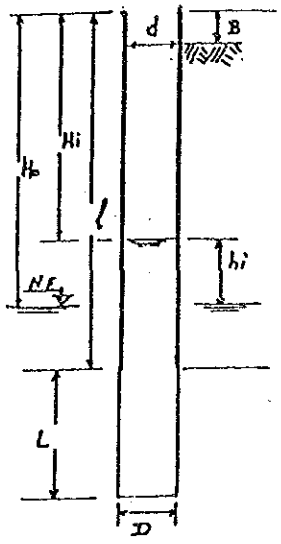
PROJECT : TAMBO 10

SURVEY :

TEST OF LE FRANC PERMEABILITY N°3
(CONSTANT LOAD)

Date : 27-09-84	Driller : F. Vilca
Boring : D1-2	Performed by : G. Lazo
Depth of Test : 25.15 - 30.00m	Revised by :
Phreatic level: 1.70 m.	Zone : PUERTO PRADO

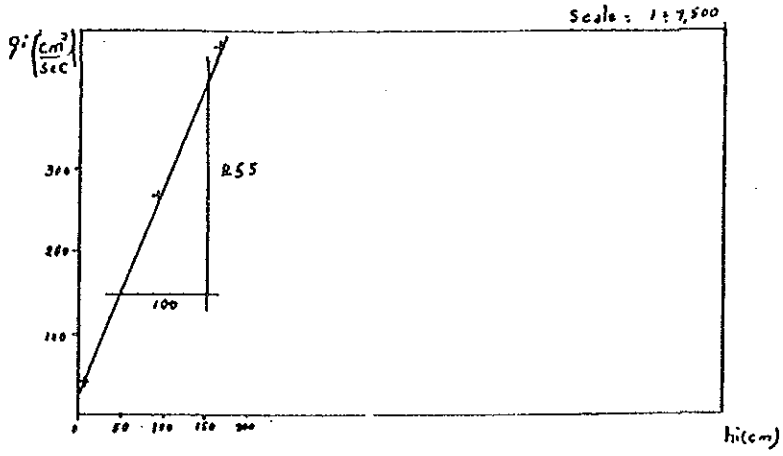
DIAGRAM



DATA

D =	7.315 cm	Ho =	170 cm
d =	7.62 cm	B =	00 cm
l =	2515 cm	L =	485 cm

T° of boring water : 25°C
T° of river water : 24°C
River Level : 1.95 m.



Hour	Ho (cm)	Hi (cm)	hi (cm)	Vi (cm³)	ti (sec)	qi (cm³/sec)	K1 (cm/sec)
8h 30'	170	00	170	26,200	60	436.67	4.12×10^{-3}
9h 00'	170	75	95	15,700	60	261.67	4.42×10^{-3}
9h 30'	170	160	10	2,300	60	38.33	6.15×10^{-3}

OBSERVATIONS

$K_2 = 4.09 \times 10^{-3}$ cm/sec.

$hi = Ho - Hi$
$qi = Vi / ti$
$K_1 = qi / c\,hi$
$K_2 = m / c$

Ind: C = Form coefficient
m = Straight line gradient
K' = Net Permeability coefficient

LE FRANC PERMEABILITY RATE

$$\frac{L}{D} \quad \frac{485}{7.315} = 66.30$$

$$C = \frac{2\pi L}{Ln\left(\frac{2L}{D}\right)}$$

$$C = \frac{2\pi\ 485}{Ln\left(\frac{2 \times 485}{7.315}\right)} \qquad C = 623.51$$

$$K_1 = \frac{q_i}{c\ h_i}$$

$$K_1 = \frac{436.67}{623.51 \times 170} = 4.12 \times 10^{-3}\ cm/sec.$$

$$K_1 = \frac{261.67}{623.51 \times 95} = 4.42 \times 10^{-3}\ cm/sec.$$

$$K_1 = \frac{38.33}{623.51 \times 10} = 6.15 \times 10^{-3}\ cm/sec.$$

$$m = \frac{q_i}{h_i} = \frac{255}{100} = 2.55$$

$$K_2 = \frac{m}{C} \qquad \frac{2.55}{623.51}$$

$$K_2 = 4.09 \times 10^{-3}\ cm/sec.$$

PERMEABILITY TEST IN DRILL HOLE (SHEET 13 OF 34)

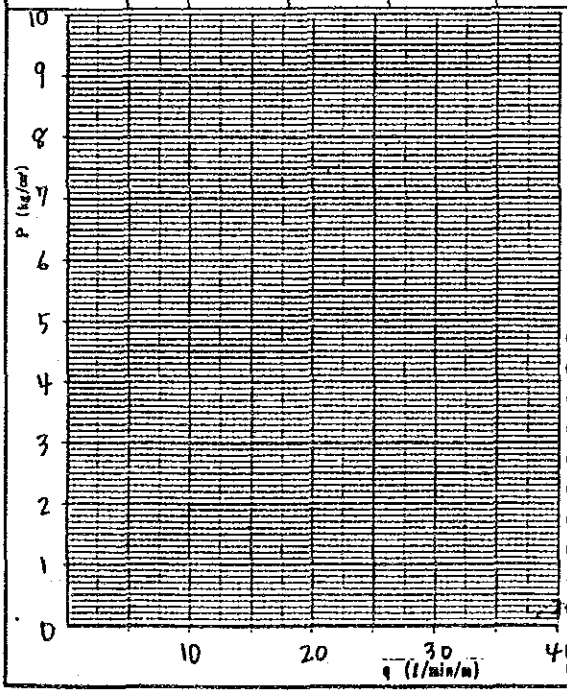
ENE RIVER PROJECT TAMBO 10 HOLE No. DT-2

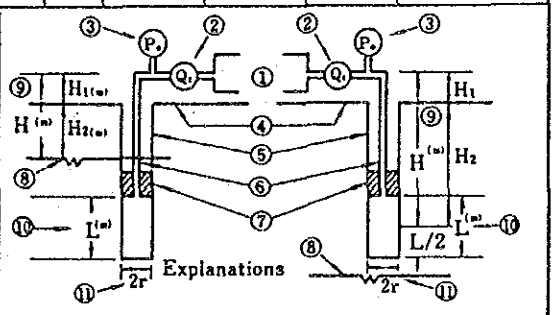
LOCATION PUERTO PRADO
ELEVATION 284 m
COORDINATE
ANGLE FROM HOLIZONTAL 90°
BEARING OF ANGLE HOLE —

DEPTH OF HOLE 30.00 m
DIAMETER OF HOLE 7.315 cm
DRILLED DEPTH 30.00 m
LEVEL OF WATER TABLE
BEFORE.T. 1.80 m AFTER.T. 1.80 m

TEST DATE 26-09-84
TESTED BY G. LAZO
DRILLED BY F. VILCA
CHECKED BY
T° of boring water: 25°

Test section(m) From	To	L (m)	H_1 (m)	H_2 (m)	P_o (kg/cm²)	P (kg/cm²)	t (min)	Q_t (ℓ)	Q_o (ℓ/min)	L_u (Lugeon)	K (cm/sec)
25.0	30.0	5.0	0.50	1.80	0	0.230	1	116.5	116.5	1.165	1.322×10^{-2}
									↓		
								X	q (ℓ/min/m)		
									23.30		





① : Pump
② : Flow meter
③ : Pressure gauge
④ : Ground surface
⑤ : Drill hole
⑥ : Injection pipe
⑦ : Packer
⑧ : Water table
⑨ : Hydrostatic head
⑩ : Length of test section
⑪ : Diamater of hole

P_o : Gauge pressure
H_1 : Height of Pressure gauge
H_2 : Depth of Ground water
P : Effective pressure
$P = P_o + H^{(m)}/10$, $H = H_1 + H_2$
t : Injected time
Q_t : Water volume during time in "t"
Q_o : Water volume per one min.
: Lugeon value in ℓ/min/m/10 kg/cm²
L_u : Coefficient of permeability
K

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PERMEABILITY TEST IN DRILL. HOLE (SHEET 14 OF 34)

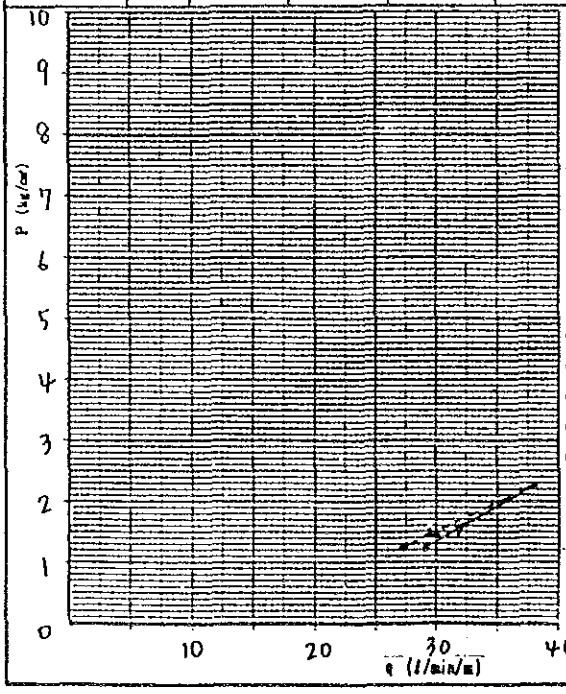
PROJECT TAMBO 10 HOLE No. DT-2

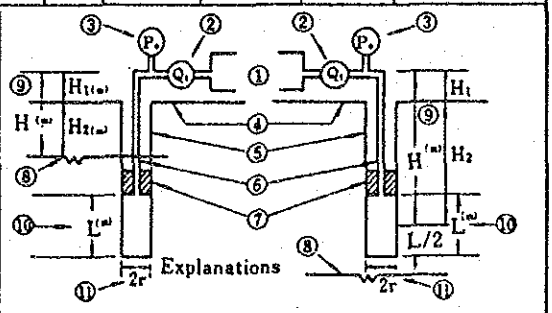
LOCATION PUERTO PRADO
ELEVATION 284 m
COORDINATE
ANGLE FROM HOLIZONTAL 90°
BEARING OF ANGLE HOLE —

DEPTH OF HOLE 35.00 m
DIAMETER OF HOLE 7.315 cm
DRILLED DEPTH 35.00 m
LEVEL OF WATER TABLE
BEFORE.T. 1.80 m AFTER.T. 1.80m

TEST DATE 27-09-84
TESTED BY G. LAZO
DRILLED BY F. VILCA
CHECKED BY
T° of boring water: 25°C

Test section(m) From	To	L (m)	H_1 (m)	H_2 (m)	P_o (kg/cm²)	P (kg/cm²)	t (min)	Q_t (ℓ)	Q_o (ℓ/min)	L_u (Lugeon)	K (cm/sec)
32.0	35.0	3.0	0.50	1.80	1	1.23	10	880	88.0	238.482	2.788×10^{-3}
〃	〃	〃	〃	〃	2	2.23	10	1.145	114.5	171.151	2.001×10^{-3}
〃	〃	〃	〃	〃	1	1.23	10	838	83.8	227.100	2.655×10^{-3}
									↓		
								× q (ℓ/min/m)			
									29.33		
									38.17		
									27.93		
			Lu=106857		K=1.249	$\times 10^{-3}$					





① : Pump
② : Flow meter
③ : Pressure gauge
④ : Ground surface
⑤ : Drill hole
⑥ : Injection pipe
⑦ : Packer
⑧ : Water table
⑨ : Hydrostatic head
⑩ : Length of test section
⑪ : Diamater of hole

P_o : Gauge pressure
H_1 : Height of Pressure gauge
H_2 : Depth of Ground water
P : Effective pressure
$P = P_o + H(m)/10$, $H = H_1 + H_2$
t : Injected time
Q_t : Water volume during time in "t"
Q_o : Water volume per one min.
: Lugeon value in ℓ/min/m/10kg/cm²
L_u : Coefficient of permeability
K

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PERMEABILITY TEST IN DRILL HOLE (SHEET 15 OF 34)

PROJECT TAMBO 10 HOLE No. DT-2

LOCATION PUERTO PRADO
ELEVATION 284 m
COORDINATE
ANGLE FROM HOLIZONTAL 90°
BEARING OF ANGLE HOLE —

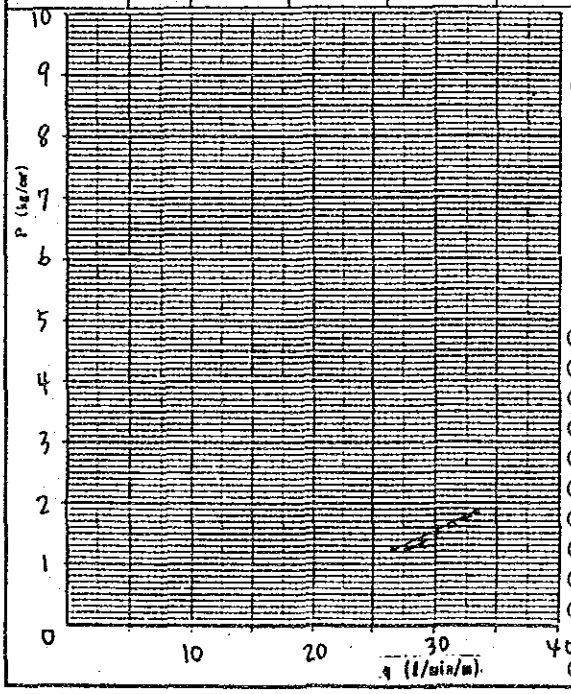
DEPTH OF HOLE 40.00 m
DIAMETER OF HOLE 7.315 cm
DRILLED DEPTH 40.00 m
LEVEL OF WATER TABLE
BEFORE.T. 1.90 m AFTER.T. 1.70 m

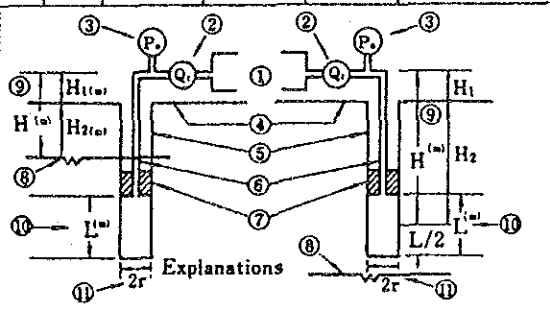
TEST DATE 28-09-84
TESTED BY G. LAZO
DRILLED BY F. VILCA
CHECKED BY
T° of boring water: 26°C

Test section(m) From	To	L (m)	H_1 (m)	H_2 (m)	P_o (kg/cm²)	P (kg/cm²)	t (min)	Q_t (ℓ)	Q_o (ℓ/min)	L_u (Lugeon)	K (cm/sec)
36.7	40.0	3.30	0.52	1.70	1	1.222	10	877	87.7	217.478	2.599×10^{-3}
〃	〃	〃	〃	〃	1.6	1.822	10	1.103	110.3	183.448	2.191×10^{-3}
〃	〃	〃	〃	〃	1	1.222	10	921	92.1	228.389	2.728×10^{-3}

※ q (ℓ/min/m)
26.58
33.42
27.91

L_u = 126.649 K = 1.513×10^{-3}





①: Pump
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⑪: Diamater of hole

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H_1 : Height of Pressure gauge
H_2 : Depth of Ground water
P : Effective pressure
$P = P_o + H(m)/10$, $H = H_1 + H_2$
t : Injected time
Q_t : Water volume during time in "t"
Q_o : Water volume per one min.
: Lugeon value in ℓ/min/m/10kg/cm²
L_u : Coefficient of permeability
K

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PERMEABILITY TEST IN DRILL HOLE (SHEET 1 OF 34)

PROJECT TAMBO 10 HOLE No. DT-2

LOCATION PUERTO PRADO
ELEVATION 284 m
COORDINATE
ANGLE FROM HOLIZONTAL 90°
BEARING OF ANGLE HOLE —

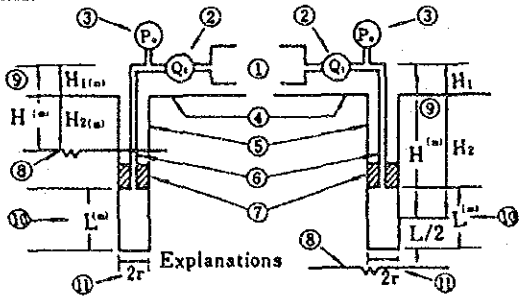
DEPTH OF HOLE 45.00 m
DIAMETER OF HOLE 9.315 cm
DRILLED DEPTH 45.00 m
LEVEL OF WATER TABLE
BEFORE.T. 1.70 m AFTER.T. 1.70 m

TEST DATE 29-09-84
TESTED BY G. LAZO
DRILLED BY F. VILCA
CHECKED BY
T° of boring water: 24°C

Test section(m) From	To	L (m)	H_1 (m)	H_2 (m)	P_o (kg/cm²)	P (kg/cm²)	t (min)	Q_t (ℓ)	Q_o (ℓ/min)	L_u (Lugeon)	K (cm/sec)
42.5	45.0	2.50	0.53	1.70	1	1.223	10	1.188	118.8	388.553	4.334×10^{-3}
									$\times \frac{1}{L}$ q (ℓ/min/m)		
									47.52		

P (kg/cm²)

q (ℓ/min/m)



Explanations

① : Pump
② : Flow meter
③ : Pressure gauge
④ : Ground surface
⑤ : Drill hole
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P : Effective pressure
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t : Injected time
Q_t : Water volume during time in "t"
Q_o : Water volume per one min.
: Lugeon value in ℓ/min/m/$10^{kg/cm^2}$
L_u : Coefficient of permeability
K

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PERMEABILITY TEST IN DRILL HOLE (SHEET 17 OF 34)

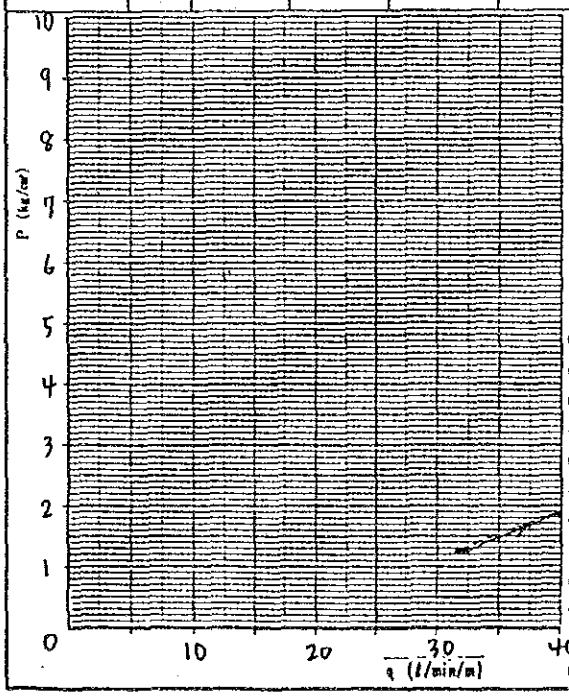
PROJECT TAMBO 10 HOLE No. DT-2

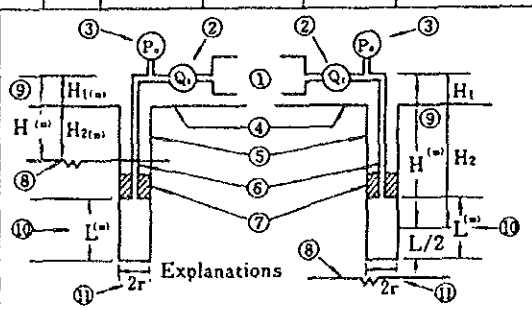
LOCATION PUERTO PRADO
ELEVATION 284 m
COORDINATE
ANGLE FROM HOLIZONTAL 90°
BEARING OF ANGLE HOLE —

DEPTH OF HOLE 60.00 m
DIAMETER OF HOLE 7.315 cm
DRILLED DEPTH 50.00 m
LEVEL OF WATER TABLE
BEFORE.T. 1.50 m AFTER.T. 1.50 m

TEST DATE 30-09-84
TESTED BY G. LAZO
DRILLED BY H. VILCA
CHECKED BY
T° of boring water: 28°C

Test section (m) From	To	L (m)	H_1 (m)	H_2 (m)	P_o (kg/cm²)	P (kg/cm²)	t (min)	Q_t (ℓ)	Q_o (ℓ/min)	L_u (Lugeon)	K (cm/sec)
46.5	50.0	3.50	0.55	1.50	1	1.205	10	1.121	112.1	265.797	3.216×10^{-3}
〃	〃	〃	〃	〃	1.6	1.805	10	1.390	139.0	220.024	2.662×10^{-3}
〃	〃	〃	〃	〃	1	1.205	10	1.115	111.5	264.375	3.199×10^{-3}
									※ q (ℓ/min/m)		
									32.03		
									39.71		
									31.86		
		Lu = 144.606			K = 1.750×10^{-3}						





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H_2 : Depth of Ground water
P : Effective pressure
$P = P_o + H(m)/10,\ H = H_1 + H_2$
t : Injected time
Q_t : Water volume during time in "t"
Q_o : Water volume per one min.
: Lugeon value in ℓ/min/m/10(kg/cm²)
L_u : Coefficient of permeability
K

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(3) Drillhole DT- 3 Records of Permeability Tests

GEOTEC S.A.

PROJECT : TAMBO 10

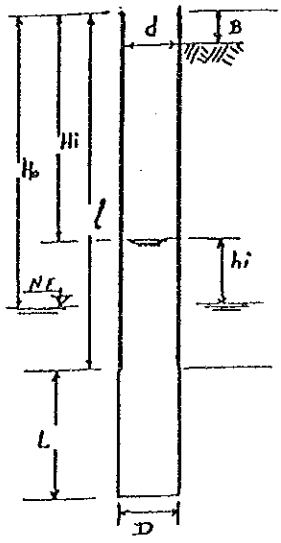
Sheet (18 – 34)

SURVEY :

TEST OF LE FRANC PERMEABILITY N° 2
(CONSTANT LOAD)

Date : 16 - 09-86	Driller : C. Huayta
Boring : DT- 3	Performed by : G. Lazo
Depth of Test : 12.80 m.	Revised by :
Phreatic level: 2.44 m.	Zone : PUERTO PRADO

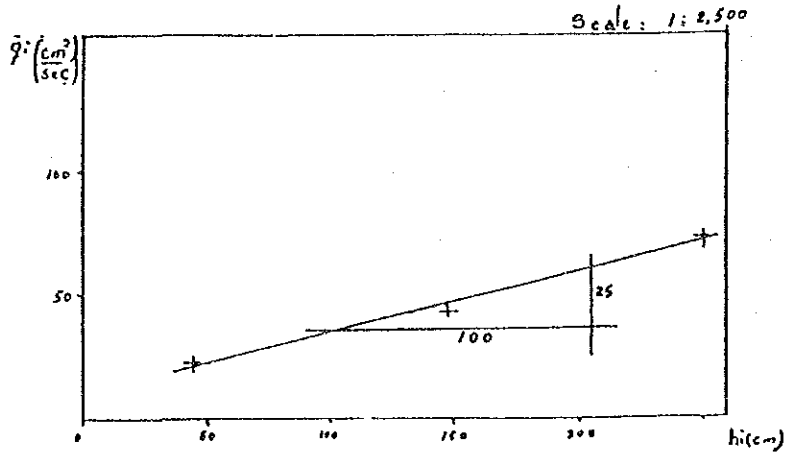
DIAGRAM



DATA

D =	9.27	cm	Ho =	244	cm
d =	10.16	cm	B =	10	cm
l =	1,290	cm	L =	00	cm

T° of boring water : 25°C
T° of river water : 25°C
River Level : 2.15 m.



Hour	Ho (cm)	Hi (cm)	hi (cm)	Vi (cm³)	ti (sec)	qi (cm²/sec)	Ki (cm/sec)
10h30'	244	00	244	5,000	70	71.43	1.44×10^{-2}
	244	100	144	5,000	108	42.30	1.45×10^{-2}
	244	200	44	500	23	21.74	2.43×10^{-2}

OBSERVATIONS

$K_2 = 1.23 \times 10^{-3}$ cm/sec.

hi = Ho - Hi
qi = Vi / ti
Ki = qi / c hi
K2 = m / c

Where : C = Form coefficient
m = Straight line gradient
K' = Net Permeability coefficient

LE FRANC PERMEABILITY RATE

$$\frac{L}{D} = 0$$

$$C = 2d = 2 \times 10.16$$

$$C = 20.32$$

$$K_1 = \frac{q_i}{C h_i}$$

$$K_1 = \frac{71.43}{20.32 \times 244} = 0.01441 = 1.44 \times 10^{-2} \text{ cm/sec.}$$

$$K_1 = \frac{42.30}{20.32 \times 144} = 0.01446 = 1.45 \times 10^{-2} \text{ cm/sec.}$$

$$K_1 = \frac{21.74}{20.32 \times 44} = 0.02431 = 2.43 \times 10^{-2} \text{ cm/sec.}$$

$$m = \frac{q_i}{h_i} = \frac{26}{100} = 0.25$$

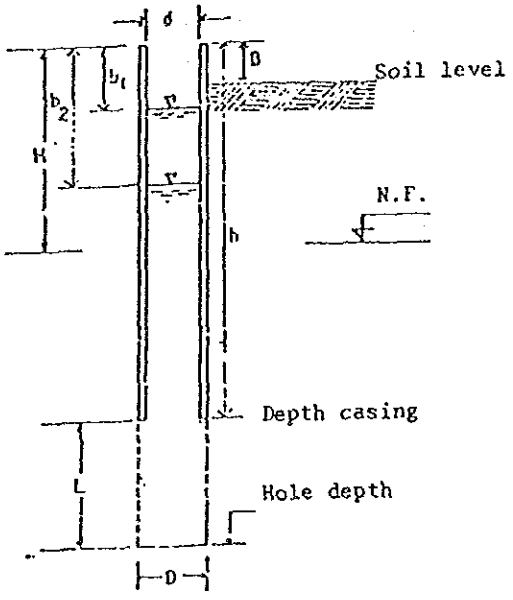
$$K_2 = \frac{m}{C} = \frac{0.25}{20.32} = 0.01230$$

$$K_2 = 1.23 \times 10^{-2} \text{ cm/sec.}$$

LE FRANC TEST N° 1
VARIABLE LOAD

Sheet (20 – 34)

Structure	:	Drilling N° :	DT - 3
Date	: 15 - 09 - 84	Depth of Test :	8.86 - 9.45 m.
Performed	: G. LAZO	Operator :	C. HUAYTA
Revised	:	Depth of Phreatic Level:	2.45 m.



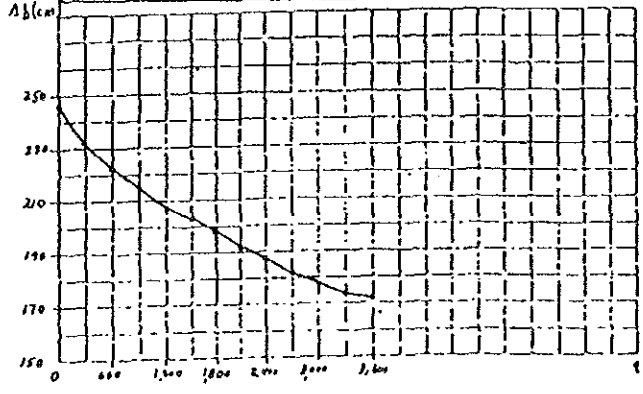
D = 0.0927 m.	H = 2.45 m.
d = 0.1016 m.	B = 0.14 m.
h = 9.00 m.	L = 0.59 m.
C =	

t°- Temperature of boring water: 27°C

t°- Temperature of river water : 26°C

River Level : 2.10 m.

Hour	Chronometer min	Time sec	bi cm.	Δb cm.
15h 30'	5	300	13.2	231.8
	10	600	22.3	222.7
	15	900	29.5	215.5
	20	1,200	36.3	208.7
	25	1,500	42.0	203.0
	30	1,800	47.3	197.7
	35	2,100	52.0	193.0
	40	2,400	57.5	187.5
	45	2,700	62.5	182.5
	50	3,000	66.6	178.4
	55	3,300	71.0	174.0
	60	3,600	74.0	171.0



OBSERVATIONS

$\frac{L}{D} = \frac{59}{9.27} = 6.36$

$C = \frac{2\pi L}{L_n\left(\frac{2L}{D}\right)} = \frac{2\pi\ 59}{L_n\left(\frac{2\times 59}{9.27}\right)}$

$C = \frac{370.708}{2.544}$ $\quad C = 145.72$

$t_1 = 1,200 \longrightarrow h_1 = 208.7$

$t_2 = 2,400 \longrightarrow h_2 = 187.5$

$K = \frac{\pi D^2}{4C(t_2 - t_1)} \log \frac{h_2}{h_1}$

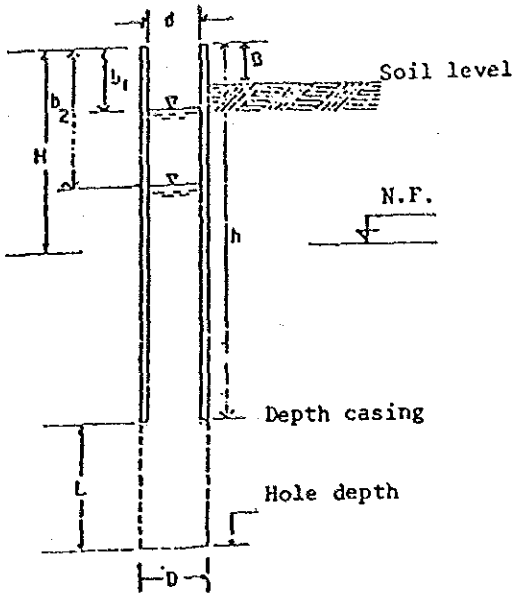
$K = \frac{\pi\ (9.27)^2}{4\,(145.72)(2,400 - 1,200)} \log \frac{187.5}{208.7}$

$K = \frac{269.966}{699456} \times 0.107$

$K = 4.13 \times 10^{-5}$ cm/sec.

LE FRANC TEST N° 3
VARIABLE LOAD

Structure :		Drilling N° :	D T - 3
Date :	17- 09 - 84	Depth of Test :	14.20 - 15.05 m.
Performed :	G. LAZO	Operator :	J. CORNELIO
Revised :		Depth of Phreatic Level:	2,50 m.



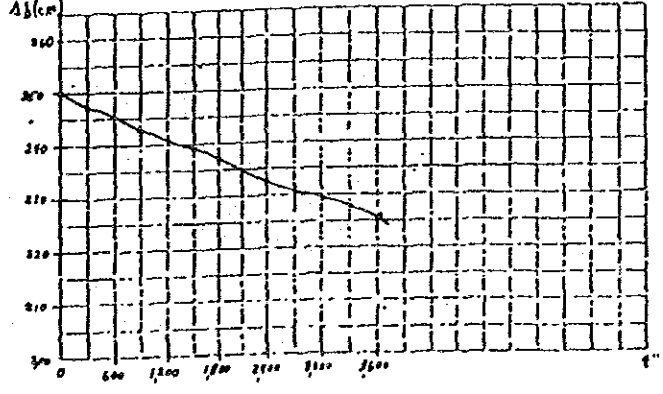
D = 0.0927 m.		H = 2.50	m.
d = 0.1016 m.		B = 0.12	m.
h = 14.32 m.		L = 0.85	m.
C =			

t°- Temperature of boring water: 27°C

t°- Temperature of river water : 27°C

River Level :

Hour	Chronometer min/	Time sec	b_i cm.	Δb cm.
		0	2.6	240
15h 00'	5	300	4.9	247.4
	10	600	7.2	245.1
	15	900	9.5	242.8
	20	1,200	11.0	240.7
	25	1,500	13.3	239.0
	30	1,800	15.4	236.7
	35	2,100	17.4	234.6
	40	2,400	19.9	232.6
	45	2,700	21.3	230.7
	50	3,000	22.5	228.7
	55	3,300	24.5	227.5
	60	3,600		225.5



OBSERVATIONS

$\frac{L}{D} = \frac{85}{9.27} = 9.17$

$C = \frac{2\pi L}{L_n\left(\frac{2L}{D}\right)} = \frac{2\pi 85}{L_n\left(\frac{2\times 85}{9.27}\right)}$

$C = \frac{534.071}{2.909}$ $\quad C = 183.59$

$t_1 = 1,200 \longrightarrow h_1 = 240.7$

$t_2 = 2,400 \longrightarrow h_2 = 232.6$

$K = \frac{\pi D^2}{4C(t_2 - t_1)} \log_e \frac{h_2}{h_1}$

$K = \frac{\pi (9.27)^2}{4(183.59)(1,200)} \log_e \frac{232.6}{240.7}$

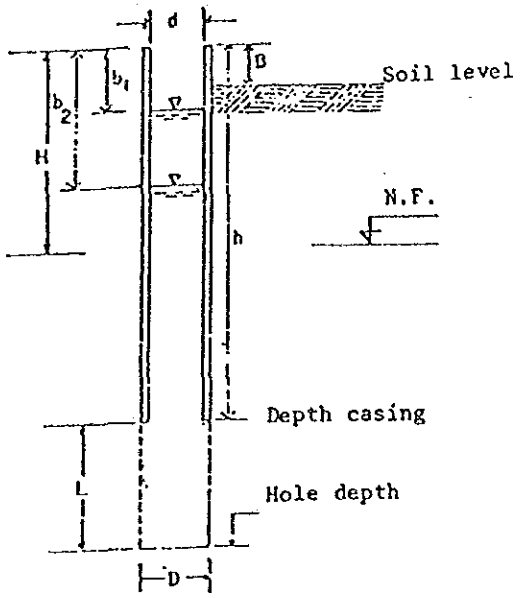
$K = \frac{269.966 \times 0.034}{881232}$

$K = 1.04 \times 10^{-5}$ cm/sec.

LE FRANC TEST N° 4

VARIABLE LOAD

Structure	:	Drilling N° :	D T - 3
Date	: 23 - 09 - 84	Depth of Test :	25.00 m.
Performed	: G. LAZO	Operator :	J. CORNELIO
Revised	:	Depth of Phreatic Level:	2.15 m.



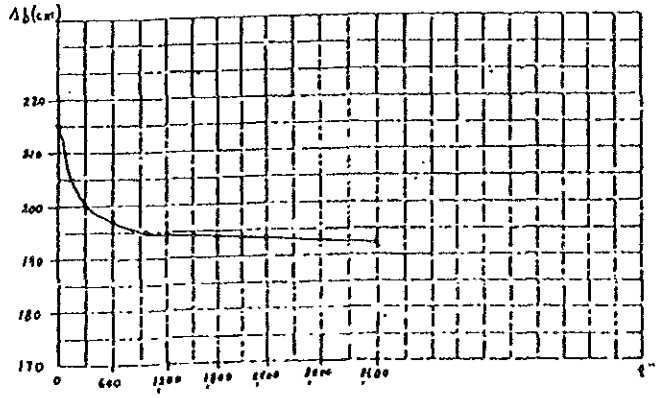
D = 0.0927 m.		H = 2.15	m.
d = 0.1016 m.		B = 0.05	m.
h = 25.05 m.		L = 00	m.
C =			

t°- Temperature of boring water: 27°C

t°- Temperature of river water : 27°C

River Level : 2.10 m.

Hour	Chronometer min/	Time sec	bi cm.	Δb cm.
07h 30'	2' 30"	150	9.8	205.2
	5'	300	14.8	200.2
	10'	600	18.1	196.9
	16'	960	19.7	195.3
	20'	1,200	20.3	194.7
	25'	1,500	20.8	194.2
	30'	1,800	21.3	193.7
	40'	2,400	21.7	193.3
	50'	3,000	22.0	193.0
	60'	3,600	22.2	192.8



OBSERVATIONS

L/D = 0

c = 2 d c = 2 x 10.16

c = 20.32

t_1 = 1,200 ⟶ h_1 = 194.7

t_2 = 2,400 ⟶ h_2 = 193.3

$$K = \frac{\pi d^2}{4C(t_2 - t_1)} \log_e \frac{h_2}{h_1}$$

$$K = \frac{\pi (10.16)^2}{4(20.32)(2,400 - 1,200)} \log_e \frac{193.3}{194.7}$$

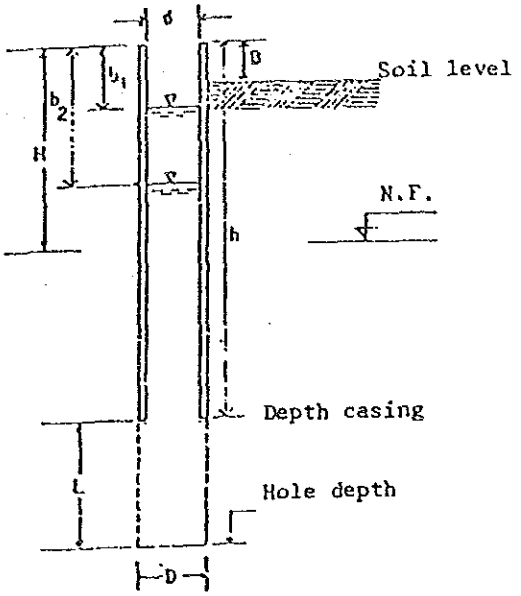
$$K = \frac{321.293}{97536} \times 7.216 \times 10^{-3}$$

$K = 2.40 \times 10^{-5}$ cm/sec.

LE FRANC TEST Nº 5

VARIABLE LOAD

Structure	:	Drilling Nº :	DT - 3
Date	: 27 - 09 - 84	Depth of Test :	35.00 m.
Performed	: G. LAZO	Operator :	J. CORNELIO
Revised	:	Depth of Phreatic Level:	3.00 m.



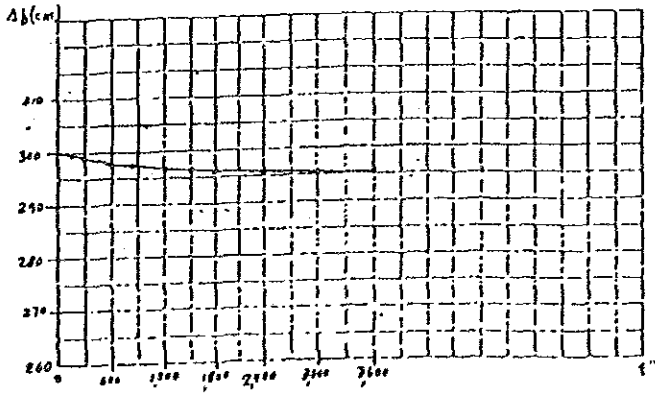
D = 0.07315 m.	H = 3.00 m.
d = 0.0762 m.	B = 0.20 m.
h = 35.20 m.	L = 00 m.
C =	

t°- Temperature of boring water: 25°C

t°- Temperature of river water : 24°C

River Level : 2.10 m.

Hour	Chronometer min/	Time sec	bi Cm.	Δb/100 Cm.
06h 10'	2' 30"	150	0.6	299.6
	5'	300	1.1	298.9
	10'	600	2.1	297.9
	14'	840	2.5	297.5
	20'	1,200	2.9	297.1
	25'	1,500	3.1	296.9
	30'	1,800	3.3	296.7
	40'	2,400	3.7	296.3
	50'	3,000	4.1	295.9
	60'	3,600	4.5	295.5



OBSERVATIONS

$C/D = 0$

$c = 2d \qquad c = 2 \times 7.62$

$c = 15.24$

$t_1 = 1.200 \rightarrow h_1 = 297.1$

$t_2 = 2.400 \rightarrow h_2 = 296.3$

$$K = \frac{\pi d^2}{4c(t_2 - t_1)} \log \frac{h_2}{h_1}$$

$$K = \frac{\pi (7.62)^2}{4(15.24)(2,400 - 1,200)} \log \frac{296.3}{297.1}$$

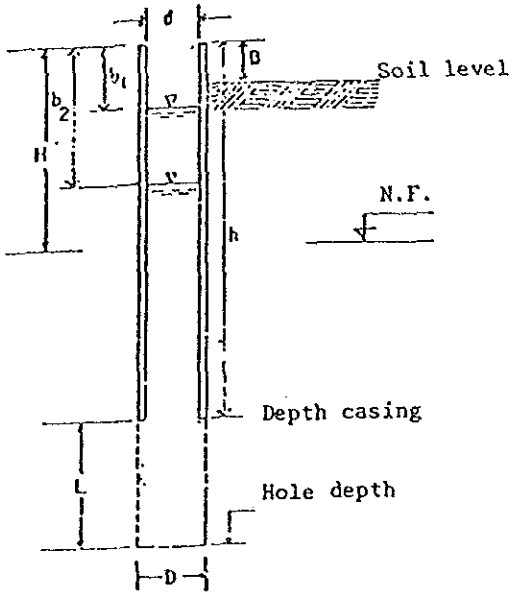
$$K = \frac{182.415}{73152} \times 2.696 \times 10^{-3}$$

$K = 6.72 \times 10^{-6}$ cm/sec.

LE FRANC TEST N° 6

VARIABLE LOAD

Structure	:	Drilling N° :	DT - 3
Date	: 29.09.84	Depth of Test :	39.00 - 40.00 m.
Performed	: G. LAZO	Operator :	J. CORNELIO
Revised	:	Depth of Phreatic Level:	1.80 m.



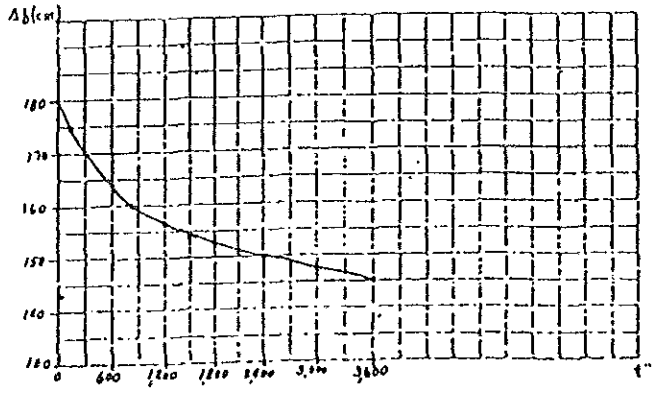
D = 0.07315 m.		H = 1.80 m.	
d = 0.0762 m.		B = 0.40 m.	
h = 39.40 m.		L = 1.00 m.	
C =			

t°- Temperature of boring water: 24°C

t°- Temperature of river water : 23°C

River Level : 2.30 m.

Hour	Chronometer min/	Time sec	bi cm.	Δb cm.
05h 20'	2'30"	150	5.4	174.6
	5'	300	10.0	170.0
	10'	600	16.4	163.6
	14'	840	19.9	160.1
	20'	1,200	23.7	156.3
	25'	1,500	25.7	154.3
	30'	1,800	27.5	152.5
	40'	2,400	30.1	149.9
	50'	3,000	32.6	147.4
	60'	3,600	35.0	145.0



OBSERVATIONS

$\frac{L}{D} = \frac{100}{7.315} = 13.67$

$C = \frac{2\pi L}{Ln\left(\frac{2L}{D}\right)} = \frac{2\pi\ 100}{Ln\left(\frac{2 \times 100}{7.315}\right)}$

$C = \frac{628.318}{3.308} \quad C = 189.94$

$t_1 = 1,200 \longrightarrow h_1 = 156.3$

$t_2 = 2,400 \longrightarrow h_2 = 149.9$

$K = \frac{\pi D^2}{4C(t_2 - t_1)} \log_e \frac{h_2}{h_1}$

$K = \frac{\pi\ (7.315)^2}{4\ (189.94)(2,400 - 1,200)} \log_e \frac{149.9}{156.3}$

$K = \frac{168.104}{91172} \times 0.042$

$K = 7.74 \times 10^{-6}$ cm/sec.

(4) Drillhole DE- 1 Records of Permeability Tests

PERMEABILITY TEST IN DRILL HOLE (SHEET 25 OF 34)

ENE RIVER PROJECT RIO ENE HOLE No. DE - 1

LOCATION PAQUITEAPANGO DEPTH OF HOLE 5.10 m TEST DATE 02-09-84

ELEVATION 345 m DIAMETER OF HOLE 9.27 cm TESTED BY G. LAZO

COORDINATE — DRILLED DEPTH 5.10 m DRILLED BY R. TOMAY

ANGLE FROM HOLIZONTAL 90° LEVEL OF WATER TABLE CHECKED BY —

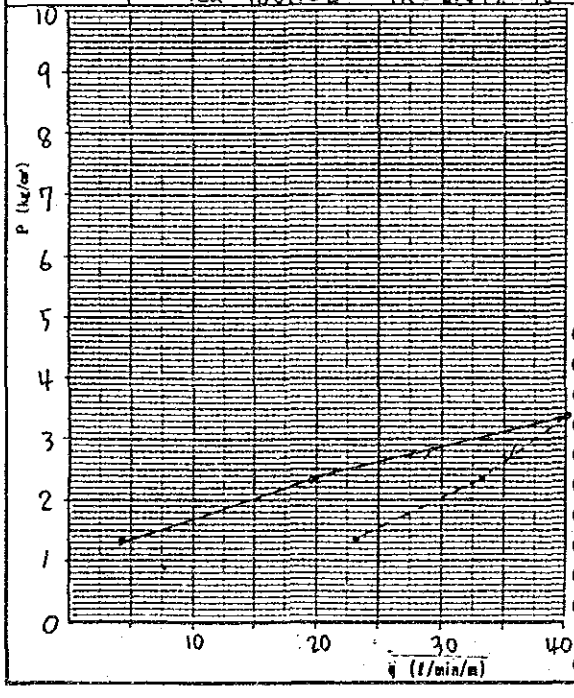
BEARING OF ANGLE HOLE — BEFORE.T. 3.00 m AFTER.T. 3.50 m

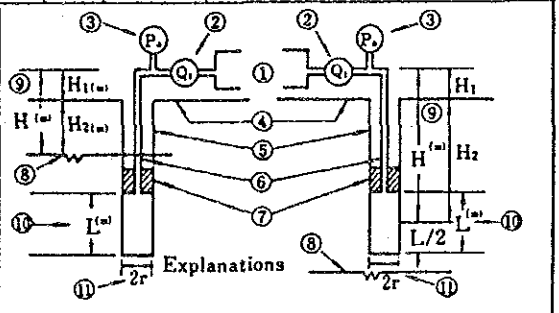
Test section(m) From	To	L (m)	H_1 (m)	H_2 (m)	P_o (kg/cm²)	P (kg/cm²)	t (min)	Q_t (ℓ)	Q_o (ℓ/min)	L_u (Lugeon)	K (cm/sec)
1.95	5.10	3.15	0.62	3.00	1	1.362	10	129	12.9	30.048	3.365×10^{-4}
〃	〃	〃	〃	〃	2	2.362	10	625	62.5	84.002	9.401×10^{-4}
〃	〃	〃	〃	〃	3	3.362	10	1.286	128.6	121.432	1.359×10^{-3}
〃	〃	〃	〃	〃	2	2.362	10	1.047	104.7	140.720	1.575×10^{-3}
〃	〃	〃	〃	〃	1	1.362	10	735	73.5	171.317	1.917×10^{-3}

※ q (ℓ/min/m)

4.10
19.84
40.83
33.24
23.33

L_u = 180.162 K = 2.017×10^{-3}





① : Pump
② : Flow meter
③ : Pressure gauge
④ : Ground surface
⑤ : Drill hole
⑥ : Injection pipe
⑦ : Packer
⑧ : Water table
⑨ : Hydrostatic head
⑩ : Length of test section
⑪ : Diamater of hole

P_o : Gauge pressure
H_1 : Height of Pressure gauge
H_2 : Depth of Ground water
P : Effective pressure
$P = P_o + H^{(m)}/10$, $H = H_1 + H_2$
t : Injected time
Q_t : Water volume during time in "t"
Q_o : Water volume per one min.
: Lugeon value in ℓ/min/m/$10^{kg/cm^2}$
L_u : Coefficient of permeability
K

ELECTRIC POWER DEVELOPMENT CO. LTD. TOKYO JAPAN

PERMEABILITY TEST IN DRILL HOLE (SHEET 26 OF 34)

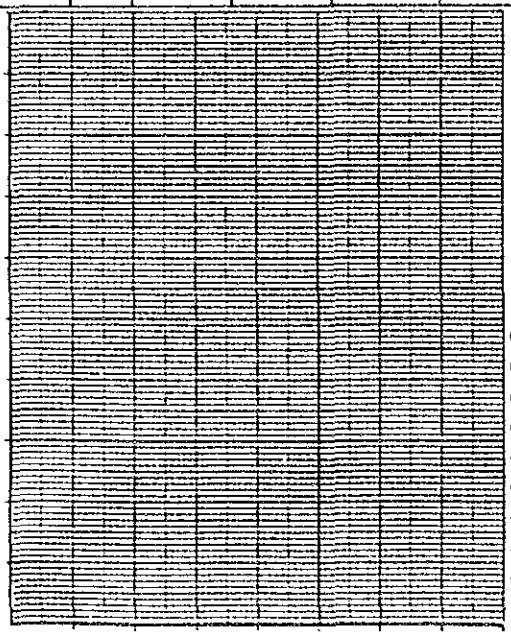
PROJECT RIO ENE HOLE No. DE-1

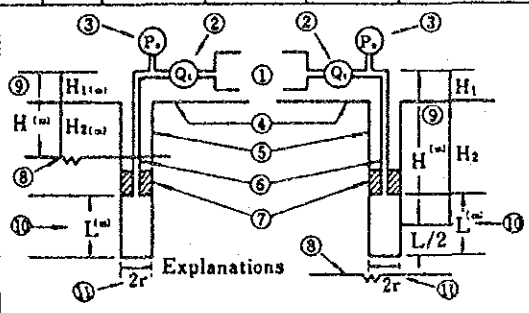
LOCATION PAQUITZAPANGO
ELEVATION 345 m
COORDINATE
ANGLE FROM HOLIZONTAL 90°
BEARING OF ANGLE HOLE —

DEPTH OF HOLE 10.00 m
DIAMETER OF HOLE 9.27 cm
DRILLED DEPTH 10.00 m
LEVEL OF WATER TABLE
BEFORE.T. 6.50m AFTER.T. 6.12 m

TEST DATE 02-09-94
TESTED BY G. LAZO
DRILLED BY R. TOMAY
CHECKED BY
T°of boring water: 28°C

Test section(m) From	To	L (m)	H_1 (m)	H_2 (m)	P_o (kg/cm²)	P (kg/cm²)	t (min)	Q_t (ℓ)	Q_o (ℓ/min)	L_u (Lugeon)	K (cm/sec)
5.0	10.0	5.0	0.60	6.50	0.5	1.21	1	111	111	183.471	2.278×10^{-3}
6.85	10.0	3.15	0.60	6.50	0.5	1.21	1	105	105	275.482	3.083×10^{-3}
7.75	10.0	2.25	0.60	6.50	1	1.71	10	00	00	00	00
					3	3.71	10	00	00	00	00
					5	5.71	10	00	00	00	00
					3	3.71	10	00	00	00	00
					1	1.71	10	00	00	00	00
									q (ℓ/min/m)		
									22.20		
									33.33		





① : Pump
② : Flow meter
③ : Pressure gauge
④ : Ground surface
⑤ : Drill hole
⑥ : Injection pipe
⑦ : Packer
⑧ : Water table
⑨ : Hydrostatic head
⑩ : Length of test section
⑪ : Diamater of hole

P_o : Gauge pressure
H_1 : Height of Pressure gauge
H_2 : Depth of Ground water
P : Effective pressure
$P = P_o + H\,(m)/10,\ H = H_1 + H_2$
t : Injected time
Q_t : Water volume during time in "t"
Q_o : Water volume per one min.
: Lugeon value in ℓ/min/m/$10^{kg/cm^2}$
L_u : Coefficient of permeability
K

ELECTRIC POWER DEVELOPMENT CO., LTD. TOKYO JAPAN

PERMEABILITY TEST IN DRILL HOLE (SHEET 27 OF 34)

PROJECT RIO ENE HOLE No. DE - 1

LOCATION PAQUILLAPANGO DEPTH OF HOLE 15.00 m TEST DATE 03-09-84

ELEVATION 345 m DIAMETER OF HOLE 9.27 cm TESTED BY G. LAZO

COORDINATE ____ DRILLED DEPTH 15.00 m DRILLED BY F. VILCA

ANGLE FROM HOLIZONTAL 90° LEVEL OF WATER TABLE CHECKED BY ____

BEARING OF ANGLE HOLE — BEFORE.T. 6.00m AFTER.T. 6.43m T° of boring water : 25°C

Test section(m) From	To	L (m)	H_1 (m)	H_2 (m)	P_o (kg/cm²)	P (kg/cm²)	t (min)	Q_t (ℓ)	Q_o (ℓ/min)	L_u (Lugeon)	K (cm/sec)
11.55	15.00	3.45	0.65	6.00	1	1.665	10	203	20.3	35.340	4.040×10^{-4}
〃	〃	〃	〃	〃	5	5.665	10	511	51.1	26.146	2.989×10^{-4}
〃	〃	〃	〃	〃	10	10.665	10	815	81.5	22.150	2.532×10^{-4}
〃	〃	〃	〃	〃	5	5.665	10	605	60.5	30.955	3.539×10^{-4}
〃	〃	〃	〃	〃	1	1.665	10	326	32.6	56.952	6.488×10^{-4}
		LG=22.448	K=2.566 x 10^{-4}								

$\bar{X}$ q (ℓ/min/m)

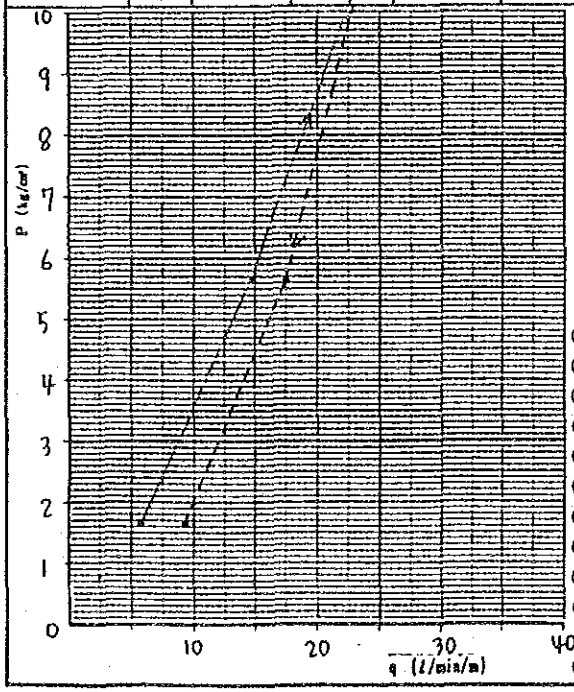
5.88

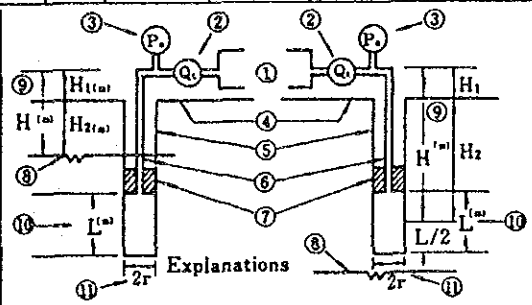
14.81

23.62

17.54

9.45





① : Pump
② : Flow meter
③ : Pressure gauge
④ : Ground surface
⑤ : Drill hole
⑥ : Injection pipe
⑦ : Packer
⑧ : Water table
⑨ : Hydrostatic head
⑩ : Length of test section
⑪ : Diamater of hole

P_o : Gauge pressure
H_1 : Height of Pressure gauge
H_2 : Depth of Ground water
P : Effective pressure
$P = P_o + H^{(m)}/10$, $H = H_1 + H_2$
t : Injected time
Q_t : Water volume during time in "t"
Q_o : Water volume per one min.
: Lugeon value in ℓ/min/m/10^4g/cm²
L_u : Coefficient of permeability
K

ELECTRIC POWER DEVELOPMENT CO., LTD. TOKYO JAPAN

PERMEABILITY TEST IN DRILL HOLE (SHEET 28 OF 34)

PROJECT RIO ENE HOLE No. DE-1

LOCATION PAQUITZAPANGO DEPTH OF HOLE 20.00 m TEST DATE 04-09-84

ELEVATION 345 m DIAMETER OF HOLE 9.27 cm TESTED BY G. LAZO

COORDINATE DRILLED DEPTH 20.00 m DRILLED BY R. TOMAY

ANGLE FROM HOLIZONTAL 90° LEVEL OF WATER TABLE CHECKED BY

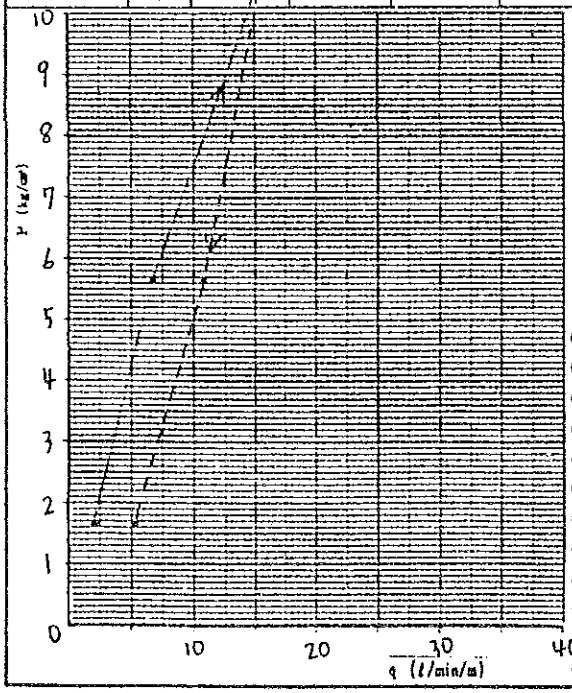
BEARING OF ANGLE HOLE — BEFORE.T. 6.00m AFTER.T. 6.20m T° of boring water: 25°C

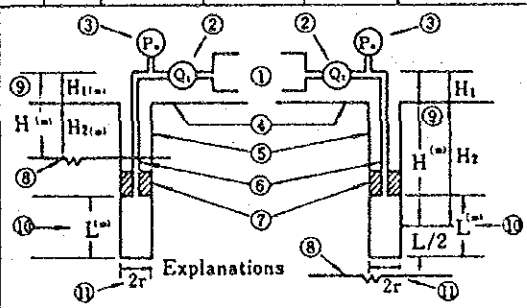
Test section (m) From	To	L (m)	H_1 (m)	H_2 (m)	P_o (kg/cm²)	P (kg/cm²)	t (min)	Q_t (ℓ)	Q_o (ℓ/min)	L_u (Lugeon)	K (cm/sec)
15.00	20.00	5.00	0.74	6.00	1	1.674	10	107	10.7	12.784	1.589×10^{-4}
〃	〃	〃	〃	〃	5	5.674	10	331	33.1	11.667	1.449×10^{-4}
〃	〃	〃	〃	〃	10	10.674	10	775	77.5	14.521	1.803×10^{-4}
〃	〃	〃	〃	〃	5	5.674	10	547	54.7	19.281	2.394×10^{-4}
〃	〃	〃	〃	〃	1	1.674	10	261	26.1	31.183	3.872×10^{-4}

$\dot{X}$ · q (ℓ/min/m)

2.14
6.62
15.50
10.94
5.22

L_u=14.303 K=1.776×10^{-4}





①: Pump
②: Flow meter
③: Pressure gauge
④: Ground surface
⑤: Drill hole
⑥: Injection pipe
⑦: Packer
⑧: Water table
⑨: Hydrostatic head
⑩: Length of test section
⑪: Diamater of hole

P_o : Gauge pressure
H_1 : Height of Pressure gauge
H_2 : Depth of Ground water
P : Effective pressure
$P = P_o + H^{(m)}/10$, $H = H_1 + H_2$
t : Injected time
Q_t : Water volume during time in "t"
Q_o : Water volume per one min.
: Lugeon value in ℓ/min/m/10kg/cm²
L_u : Coefficient of permeability
K

ELECTRIC POWER DEVELOPMENT CO., LTD. TOKYO JAPAN

PERMEABILITY TEST IN DRILL HOLE (SHEET 29 OF 34)

PROJECT RIO ENT HOLE No. DE - 1

LOCATION PAQUITZAPANGO
ELEVATION 345 m
COORDINATE
ANGLE FROM HOLIZONTAL 90°
BEARING OF ANGLE HOLE —

DEPTH OF HOLE 25.00 m
DIAMETER OF HOLE 9.27 cm
DRILLED DEPTH 25.00 m
LEVEL OF WATER TABLE
BEFORE.T. 6.05 m AFTER.T. 6.10 m

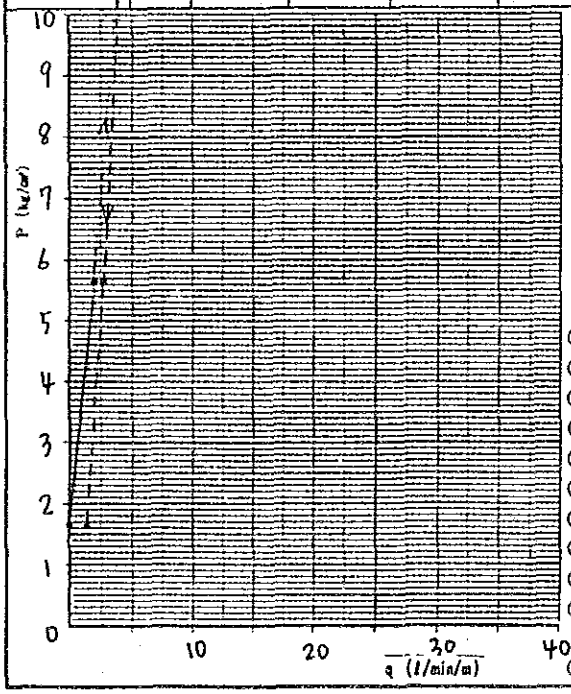
TEST DATE 04-09-84
TESTED BY G. LAZO
DRILLED BY E. VILCA
CHECKED BY
T° of boring water: 25°C

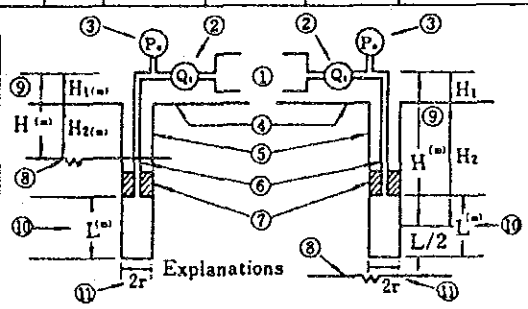
Test section(m) From	To	L (m)	H_1 (m)	H_2 (m)	P_o (kg/cm²)	P (kg/cm²)	t (min)	Q_t (ℓ)	Q_o (ℓ/min)	L_u (Lugeon)	K (cm/sec)
20.00	25.00	5.00	0.70	6.05	1	1.675	10	00	00	-	-
〃	〃	〃	〃	〃	5	5.675	10	115	11.5	4.053	5.032×10^{-5}
〃	〃	〃	〃	〃	10	10.675	10	210	21.0	3.934	4.885×10^{-5}
〃	〃	〃	〃	〃	5	5.675	10	144	14.4	5.075	6.301×10^{-5}
〃	〃	〃	〃	〃	1	1.675	10	71	7.1	8.478	1.053×10^{-4}

※ q (ℓ/min/m)

00
2.30
4.20
2.88
1.42

Lu = 3.944 K = 4.897×10^{-5}





① : Pump
② : Flow meter
③ : Pressure gauge
④ : Ground surface
⑤ : Drill hole
⑥ : Injection pipe
⑦ : Packer
⑧ : Water table
⑨ : Hydrostatic head
⑩ : Length of test section
⑪ : Diamater of hole

P_o : Gauge pressure
H_1 : Height of Pressure gauge
H_2 : Depth of Ground water
P : Effective pressure
$P = P_o + H^{(m)}/10$, $H = H_1 + H_2$
t : Injected time
Q_t : Water volume during time in "t"
Q_o : Water volume per one min.
: Lugeon value in ℓ/min/m/10kg/cm²
L_u : Coefficient of permeability
K : Coefficient of permeability

ELECTRIC POWER DEVELOPMENT CO., LTD. TOKYO JAPAN

PERMEABILITY TEST IN DRILL HOLE (SHEET 30 OF 34)

PROJECT RIO ENE HOLE No. DE - 1

LOCATION PAQUITZAPANGO
ELEVATION 345 m
COORDINATE
ANGLE FROM HOLIZONTAL 90°
BEARING OF ANGLE HOLE —

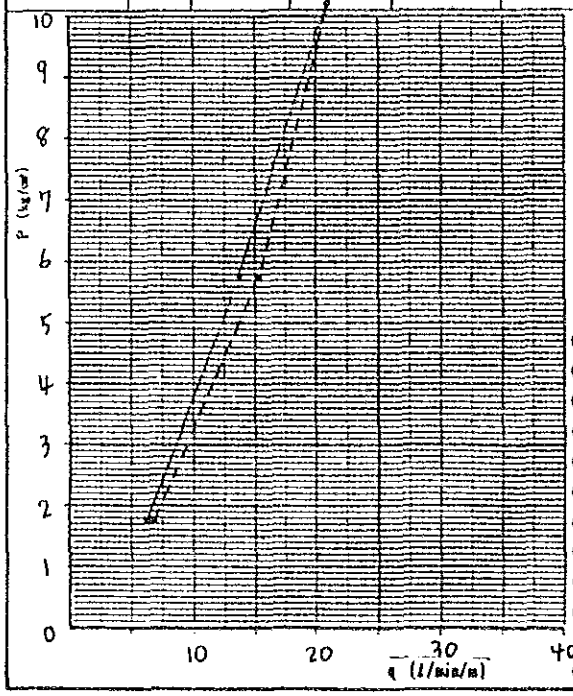
DEPTH OF HOLE 30.00 m
DIAMETER OF HOLE 7.315 cm
DRILLED DEPTH 30.00 m
LEVEL OF WATER TABLE
BEFORE.T. 6.60m AFTER.T. 6.50m

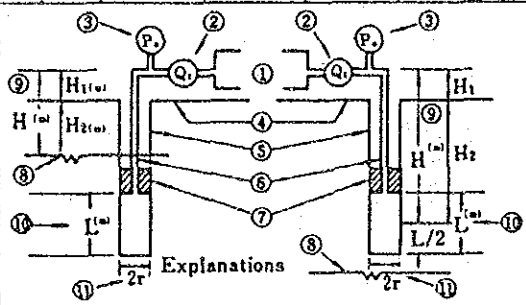
TEST DATE 05-09-24
TESTED BY G. LAZO
DRILLED BY R. TOMAY
CHECKED BY
T° of boring water : 25°C

Test section(m) From	To	L (m)	H_1 (m)	H_2 (m)	P_o (kg/cm²)	P (kg/cm²)	t (min)	Q_t (ℓ)	Q_o (ℓ/min)	L_u (Lugeon)	K (cm/sec)
25.00	30.00	5.00	0.66	6.60	1	1.726	10	323	32.3	37.428	4.882×10^{-4}
〃	〃	〃	〃	〃	5	5.726	10	691	69.1	24.135	3.148×10^{-4}
〃	〃	〃	〃	〃	9.5	10.726	10	1.053	105.3	20.595	2.687×10^{-4}
〃	〃	〃	〃	〃	5	5.726	10	761	76.1	26.580	3.467×10^{-4}
〃	〃	〃	〃	〃	1	1.726	10	346	34.6	40.093	5.230×10^{-4}

$\bar{X}$. q (ℓ/min/m)
6.46
13.82
21.06
15.22
6.92

Lu = 20.696 K = 2.700×10^{-4}





① : Pump
② : Flow meter
③ : Pressure gauge
④ : Ground surface
⑤ : Drill hole
⑥ : Injection pipe
⑦ : Packer
⑧ : Water table
⑨ : Hydrostatic head
⑩ : Length of test section
⑪ : Diamater of hole

P_o : Gauge pressure
H_1 : Height of Pressure gauge
H_2 : Depth of Ground water
P : Effective pressure
$P = P_o + H'^{(m)}/10$, $H = H_1 + H_2$
t : Injected time
Q_t : Water volume during time in "t"
Q_o : Water volume per one min.
: Lugeon value in ℓ/min/m/10kg/cm²
L_u : Coefficient of permeability
K

ELECTRIC POWER DEVELOPMENT CO., LTD. TOKYO JAPAN

PERMEABILITY TEST IN DRILL HOLE (SHEET 3 OF 34)

PROJECT RIO ENE HOLE No. DE-1

LOCATION PAQUIZAPANGO
ELEVATION 345 m
COORDINATE
ANGLE FROM HOLIZONTAL 90°
BEARING OF ANGLE HOLE —

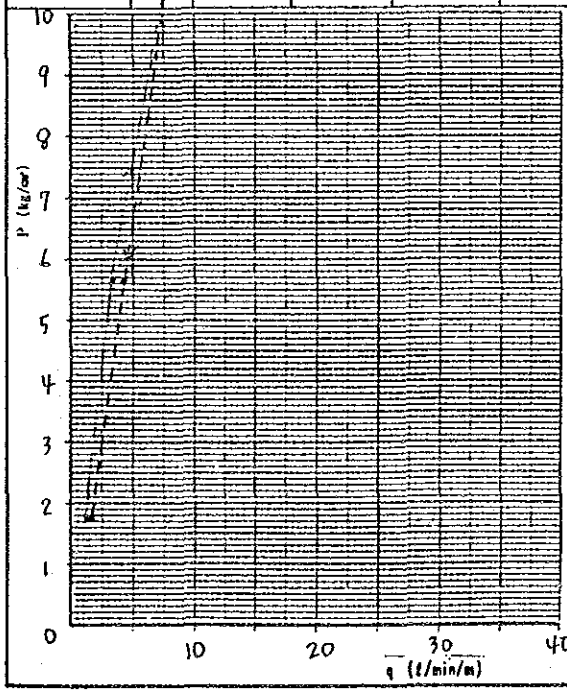
DEPTH OF HOLE 35.00 m
DIAMETER OF HOLE 7.315 cm
DRILLED DEPTH 35.00 m
LEVEL OF WATER TABLE
BEFORE T. 6.20 m AFTER T. 6.40 m

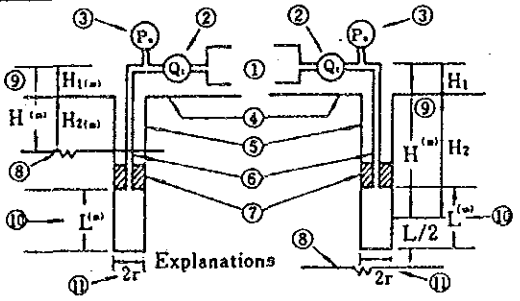
TEST DATE 05-09-84
TESTED BY G. LAZO
DRILLED BY R. TOMAY
CHECKED BY
T° of boring water : 25°C

Test section (m) From	To	L (m)	H_1 (m)	H_2 (m)	P_o (kg/cm²)	P (kg/cm²)	t (min)	Q_t (ℓ)	Q_o (ℓ/min)	L_u (Lugeon)	K (cm/sec)
30.00	35.00	5.00	0.76	6.20	1	1.696	10	68	6.8	8.019	1.046×10^{-4}
〃	〃	〃	〃	〃	5	5.696	10	179	17.9	6.285	8.199×10^{-5}
〃	〃	〃	〃	〃	10	10.696	10	397	39.7	7.423	9.684×10^{-5}
〃	〃	〃	〃	〃	5	5.696	10	221	22.1	7.760	1.012×10^{-4}
〃	〃	〃	〃	〃	1	1.696	10	97	9.7	11.439	1.492×10^{-4}

Q_o (ℓ/min/m)
1.36
3.58
7.94
4.42
1.94

$L_u = 7.333$ $K = 9.566 \times 10^{-5}$





① : Pump
② : Flow meter
③ : Pressure gauge
④ : Ground surface
⑤ : Drill hole
⑥ : Injection pipe
⑦ : Packer
⑧ : Water table
⑨ : Hydrostatic head
⑩ : Length of test section
⑪ : Diamater of hole

P_o : Gauge pressure
H_1 : Height of Pressure gauge
H_2 : Depth of Ground water
P : Effective pressure
$P = P_o + H^{(m)}/10$, $H = H_1 + H_2$
t : Injected time
Q_t : Water volume during time in "t"
Q_o : Water volume per one min.
: Lugeon value in ℓ/min/m/10kg/cm²
L_u : Coefficient of permeability
K

ELECTRIC POWER DEVELOPMENT CO., LTD. TOKYO JAPAN

PERMEABILITY TEST IN DRILL HOLE (SHEET 32 OF 34)

PROJECT RIO ENE HOLE No. DE-1

LOCATION PAQUITZAPANGO
ELEVATION 345 m
COORDINATE
ANGLE FROM HOLIZONTAL 90°
BEARING OF ANGLE HOLE —

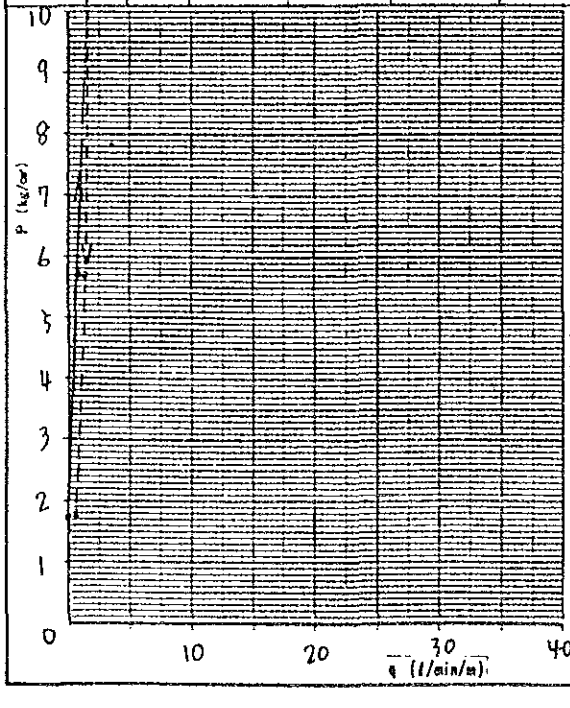
DEPTH OF HOLE 40.00 m
DIAMETER OF HOLE 7.315 cm
DRILLED DEPTH 40.00 m
LEVEL OF WATER TABLE
BEFORE.T. 6.40 m AFTER.T. 6.40 m

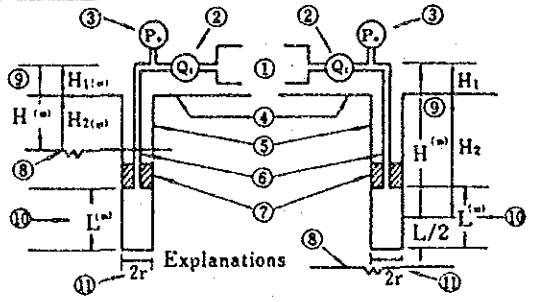
TEST DATE 06-09-84
TESTED BY G. LAZO
DRILLED BY F. VILCA
CHECKED BY
T° of boring water: 24°C

Test section(m) From	To	L (m)	H_1 (m)	H_2 (m)	P_o (kg/cm²)	P (kg/cm²)	t (min)	Q_t (ℓ)	Q_o (ℓ/min)	L_u (Lugeon)	K (cm/sec)
35.00	40.00	5.00	0.72	6.40	1	1.712	10	00	00	00	00
〃	〃	〃	〃	〃	5	5.712	10	47	4.7	1.646	2.147×10^{-5}
〃	〃	〃	〃	〃	10	10.712	10	88	8.8	1.643	2.143×10^{-5}
〃	〃	〃	〃	〃	5	5.712	10	56	5.6	1.961	2.558×10^{-5}
〃	〃	〃	〃	〃	1	1.712	10	20	2.0	2.336	3.048×10^{-5}

L_u = 1.643 K = 2.144×10^{-5}

q (ℓ/min/m)
00
0.94
1.76
1.12
0.40





① : Pump
② : Flow meter
③ : Pressure gauge
④ : Ground surface
⑤ : Drill hole
⑥ : Injection pipe
⑦ : Packer
⑧ : Water table
⑨ : Hydrostatic head
⑩ : Length of test section
⑪ : Diamater of hole

P_o : Gauge pressure
H_1 : Height of Pressure gauge
H_2 : Depth of Ground water
P : Effective pressure
$P = P_o + H^{(m)}/10$, $H = H_1 + H_2$
t : Injected time
Q_t : Water volume during time in "t"
Q_o : Water volume per one min.
: Lugeon value in ℓ/min/m/10 kg/cm²
L_u : Coefficient of permeability

ELECTRIC POWER DEVELOPMENT CO., LTD. TOKYO JAPAN

PERMEABILITY TEST IN DRILL HOLE (SHEET 33 OF 34)

PROJECT RIO ENE HOLE No. DE-1

LOCATION PAQUITZAPANGO
ELEVATION 345 m
COORDINATE
ANGLE FROM HOLIZONTAL 90°
BEARING OF ANGLE HOLE —

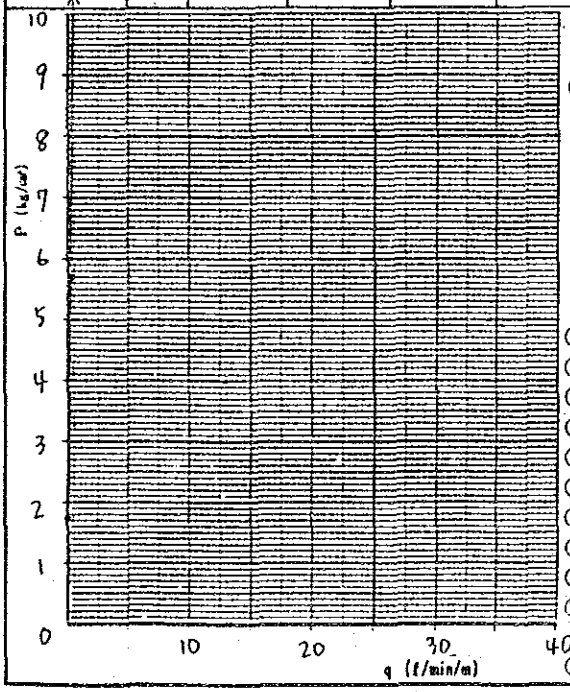
DEPTH OF HOLE 45.00 m
DIAMETER OF HOLE 7.315 cm
DRILLED DEPTH 45.00 m
LEVEL OF WATER TABLE
BEFORE.T. 6.40m AFTER.T. 6.50m

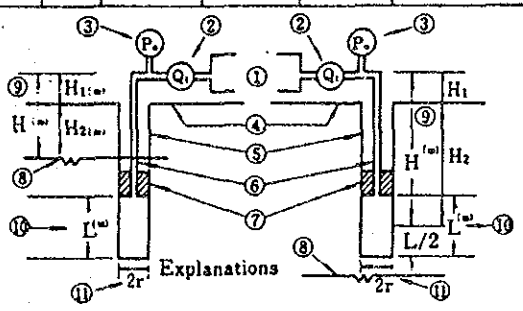
TEST DATE 06-09-84
TESTED BY G. LAZO
DRILLED BY R. TOMAY
CHECKED BY
T° of boring water: 25°c

Test section(m) From	To	L (m)	H_1 (m)	H_2 (m)	P_o (kg/cm²)	P (kg/cm²)	t (min)	Q_t (ℓ)	Q_o (ℓ/min)	L_u (Lugeon)	K (cm/sec)
40.00	45.00	5.00	0.72	6.40	1	1.712	10	00	00	00	00
"	"	"	"	"	5	5.712	10	5	0.5	0.175	2.284×10^{-6}
"	"	"	"	"	10	10.712	10	7	0.7	0.131	1.705×10^{-6}
"	"	"	"	"	5	5.712	10	00	00	00	00
"	"	"	"	"	1	1.712	10	00	00	00	00

Σq = 0.134 K = 1.752×10^{-6}

Σ q (ℓ/min/m)
00
0.10
0.14
00
00





① : Pump
② : Flow meter
③ : Pressure gauge
④ : Ground surface
⑤ : Drill hole
⑥ : Injection pipe
⑦ : Packer
⑧ : Water table
⑨ : Hydrostatic head
⑩ : Length of test section
⑪ : Diamater of hole

P_o : Gauge pressure
H_1 : Height of Pressure gauge
H_2 : Depth of Ground water
P : Effective pressure
$P = P_o + H^{(m)}/10$, $H = H_1 + H_2$
t : Injected time
Q_t : Water volume during time in "t"
Q_o : Water volume per one min.
: Lugeon value in ℓ/min/m/10kg/cm²
L_u : Coefficient of permeability
K

ELECTRIC POWER DEVELOPMENT CO. LTD. TOKYO JAPAN

PERMEABILITY TEST IN DRILL HOLE (SHEET 34 OF 34)

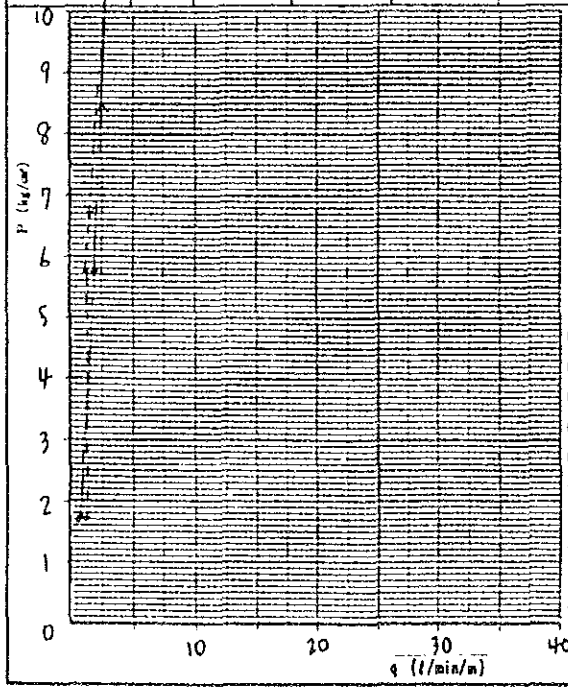
PROJECT RIO ENE HOLE No. DE-1

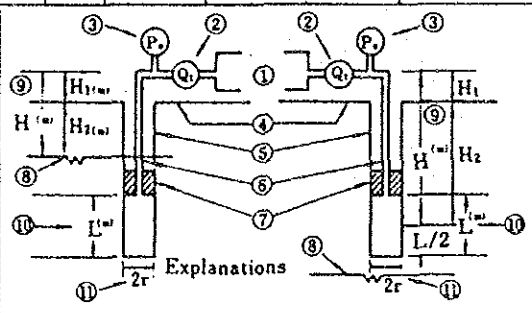
LOCATION PAQUITE APANGO
ELEVATION 345 m
COORDINATE
ANGLE FROM HOLIZONTAL 90°
BEARING OF ANGLE HOLE —

DEPTH OF HOLE 50.00 m
DIAMETER OF HOLE 7.315 cm
DRILLED DEPTH 50.00 m
LEVEL OF WATER TABLE
BEFORE.T. 6.50 m AFTER.T. 6.50 m

TEST DATE 06-09-24
TESTED BY G. LAZO
DRILLED BY F. VILCA
CHECKED BY
T° of boring water: 25°C

Test section(m) From	To	L (m)	H_1 (m)	H_2 (m)	P_o (kg/cm²)	P (kg/cm²)	t (min)	Q_t (ℓ)	Q_o (ℓ/min)	L_u (Lugeon)	K (cm/sec)
45.00	50.00	5.00	0.76	6.50	1	1.726	10	41	4.1	4.751	6.197×10^{-5}
〃	〃	〃	〃	〃	5	5.726	10	100	10.0	3.493	4.556×10^{-5}
〃	〃	〃	〃	〃	10	10.726	10	157	15.7	2.927	3.819×10^{-5}
〃	〃	〃	〃	〃	5	5.726	10	97	9.7	3.388	4.420×10^{-5}
〃	〃	〃	〃	〃	1	1.726	10	48	4.8	5.562	7.256×10^{-5}
									↓		
									※ q (ℓ/min/m)		
									0.82		
									2.00		
									3.14		
									1.94		
									0.96		
		Lu = 2.994		K = 3.880×10^{-5}							





① : Pump
② : Flow meter
③ : Pressure gauge
④ : Ground surface
⑤ : Drill hole
⑥ : Injection pipe
⑦ : Packer
⑧ : Water table
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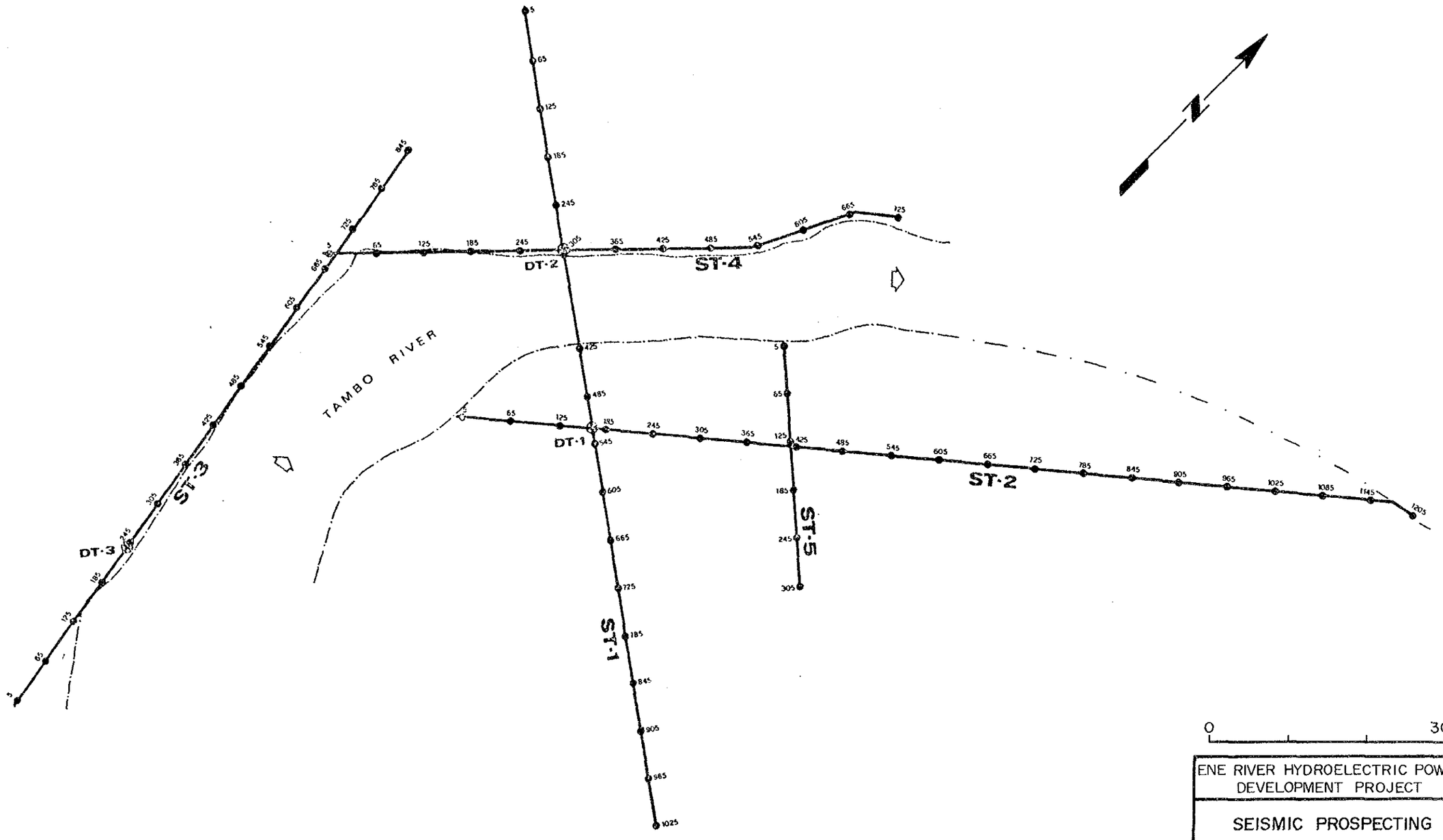
⑪ : Diamater of hole

P_o : Gauge pressure
H_1 : Height of Pressure gauge
H_2 : Depth of Ground water
P : Effective pressure
$P = P_o + H'^{(m)}/10$, $H = H_1 + H_2$
t : Injected time
Q_t : Water volume during time in "t"
Q_o : Water volume per one min.
: Lugeon value in ℓ/min/m/$10^{kg/cm^2}$
L_u : Coefficient of permeability
K

ELECTRIC POWER DEVELOPMENT CO., LTD. TOKYO JAPAN

(10) Seismic Prospecting; Locations and Time-Distance Curves of seismic Lines.



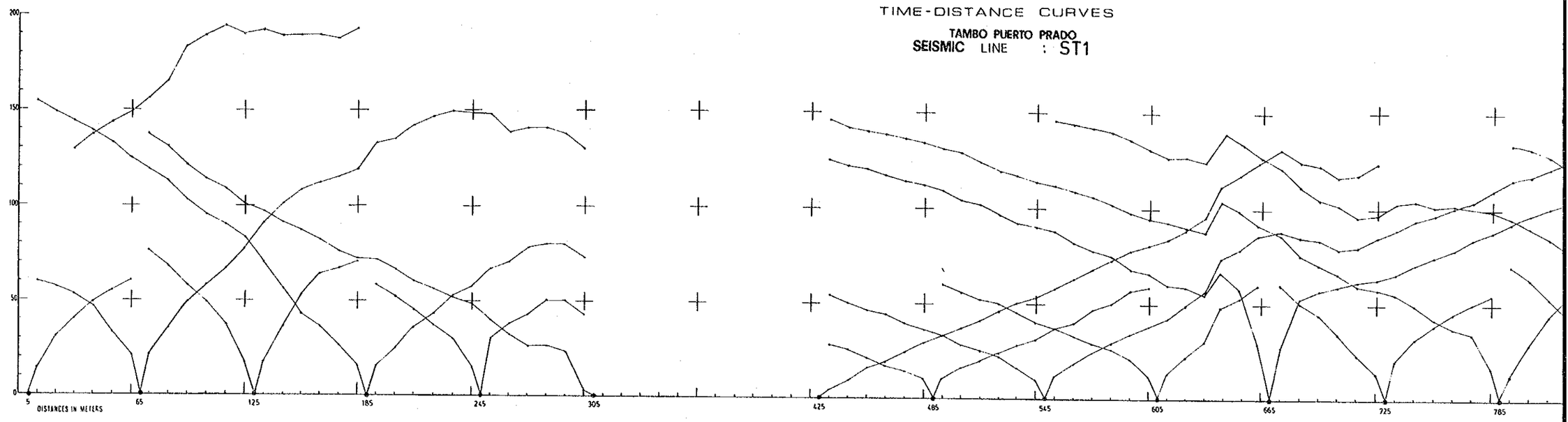
ENE RIVER HYDROELECTRIC POWER DEVELOPMENT PROJECT

SEISMIC PROSPECTING
LOCATION OF SEISMIC LINES
AT TAMBO PUERTO PRADO SITE

A-2 (10)
Sheet (1-5)

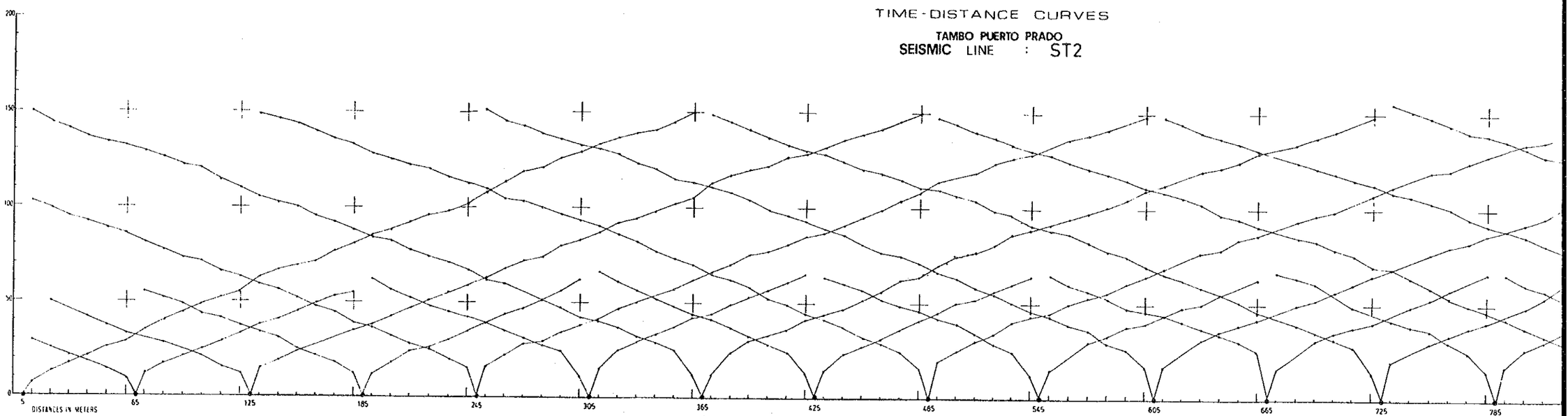
TIME-DISTANCE CURVES

TAMBO PUERTO PRADO
SEISMIC LINE : ST1



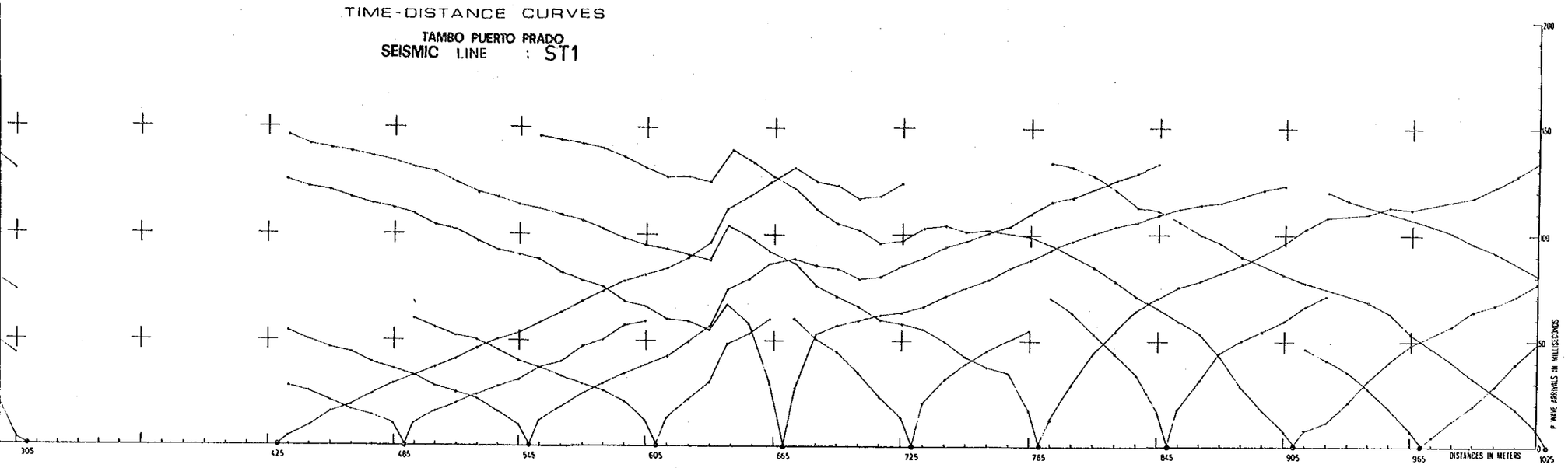
TIME-DISTANCE CURVES

TAMBO PUERTO PRADO
SEISMIC LINE : ST2



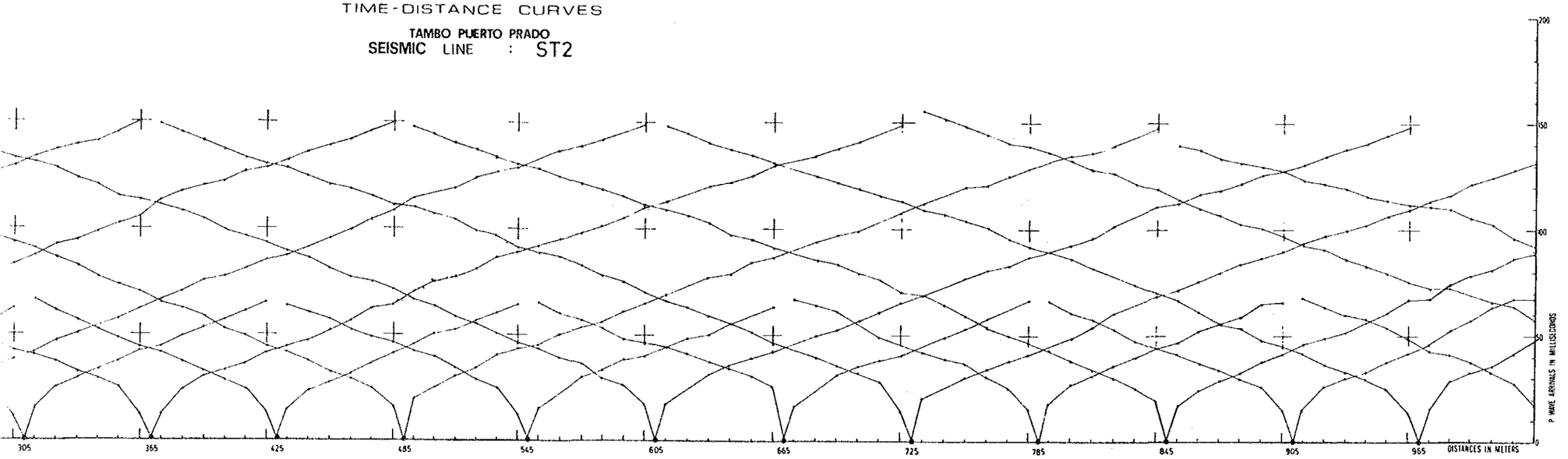
TIME-DISTANCE CURVES

TAMBO PUERTO PRADO
SEISMIC LINE : ST1



TIME-DISTANCE CURVES

TAMBO PUERTO PRADO
SEISMIC LINE : ST2



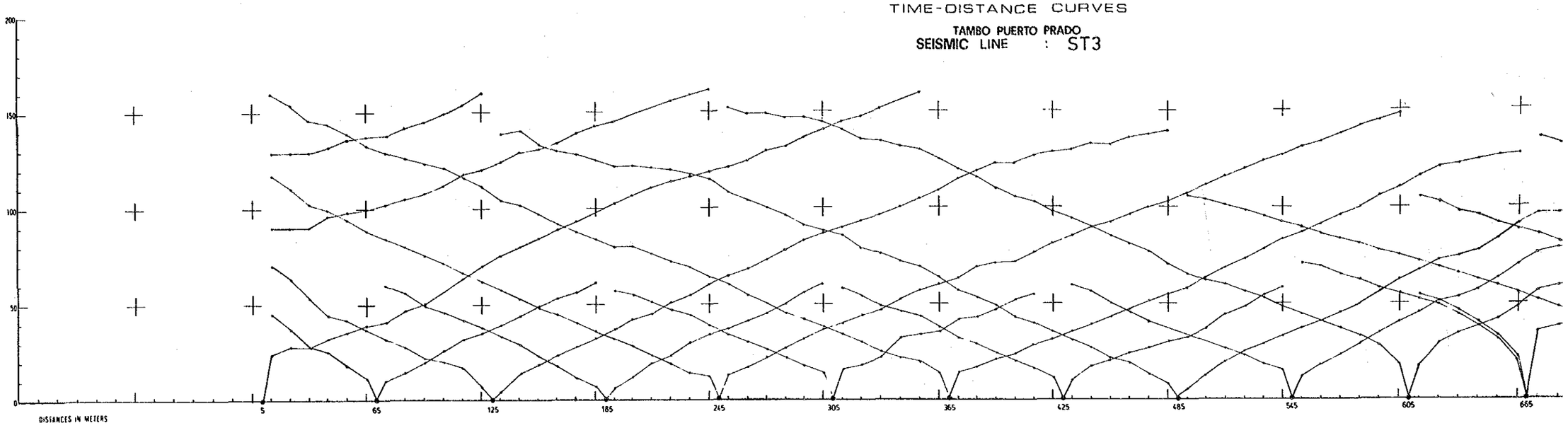
ENE RIVER HYDROELECTRIC POWER DEVELOPMENT PROJECT

SEISMIC PROSPECTING TIME-DISTANCE CURVES OF ST-1, AND ST-2, LINES AT ENE PAQUITZAPANGO SITE

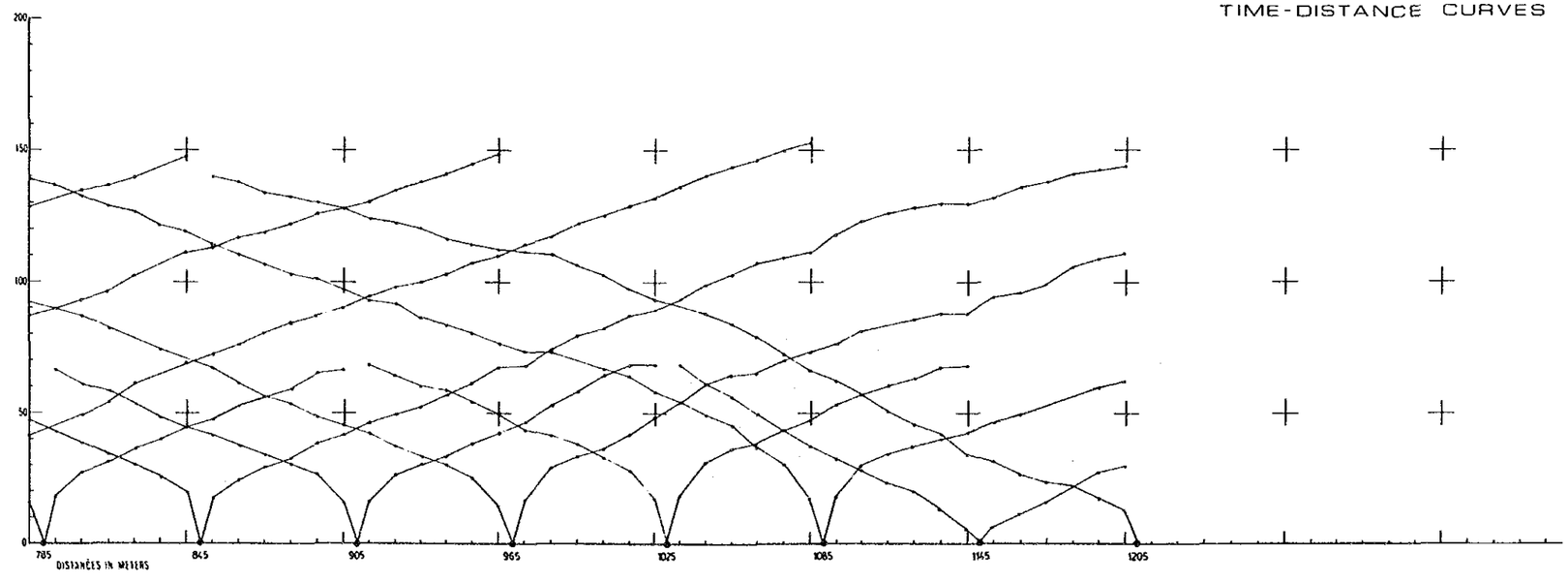
A-2 (10)
Sheet (2-5)

TIME-DISTANCE CURVES

TAMBO PUERTO PRADO
SEISMIC LINE : ST3

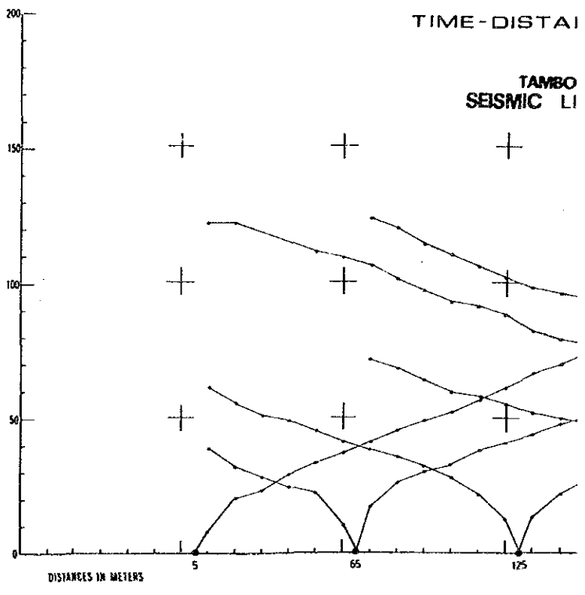


TIME-DISTANCE CURVES



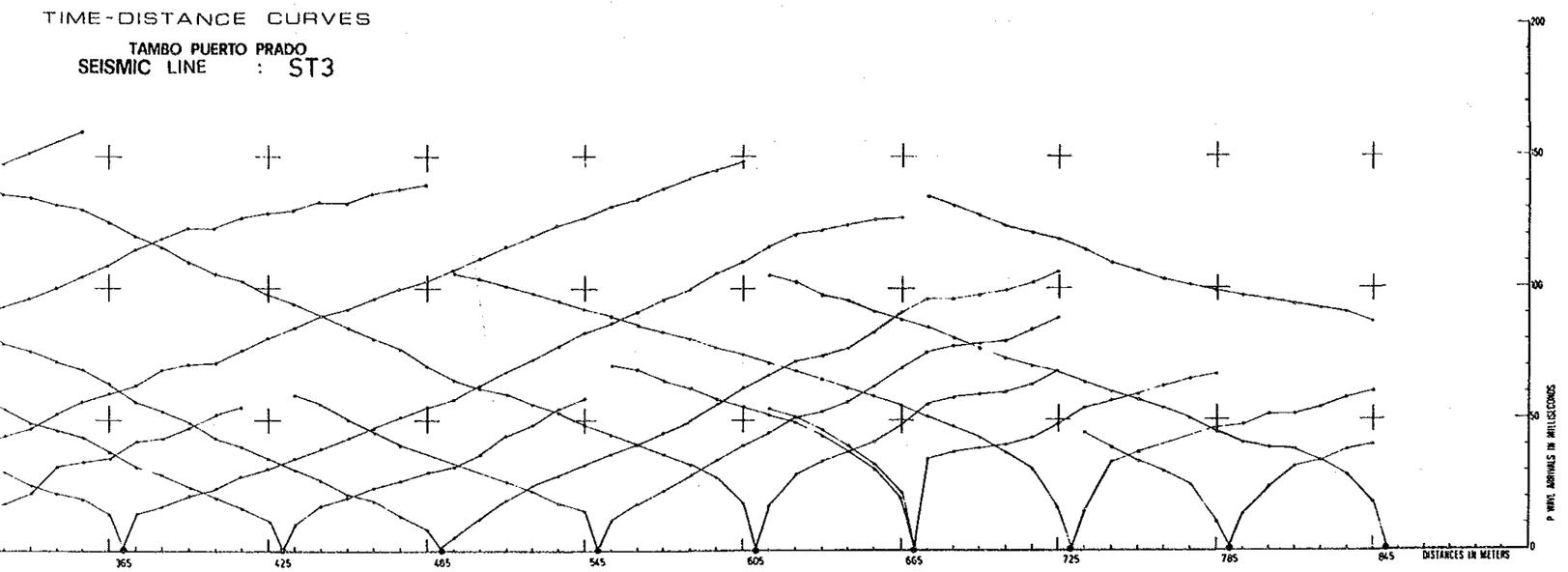
TIME-DISTAI

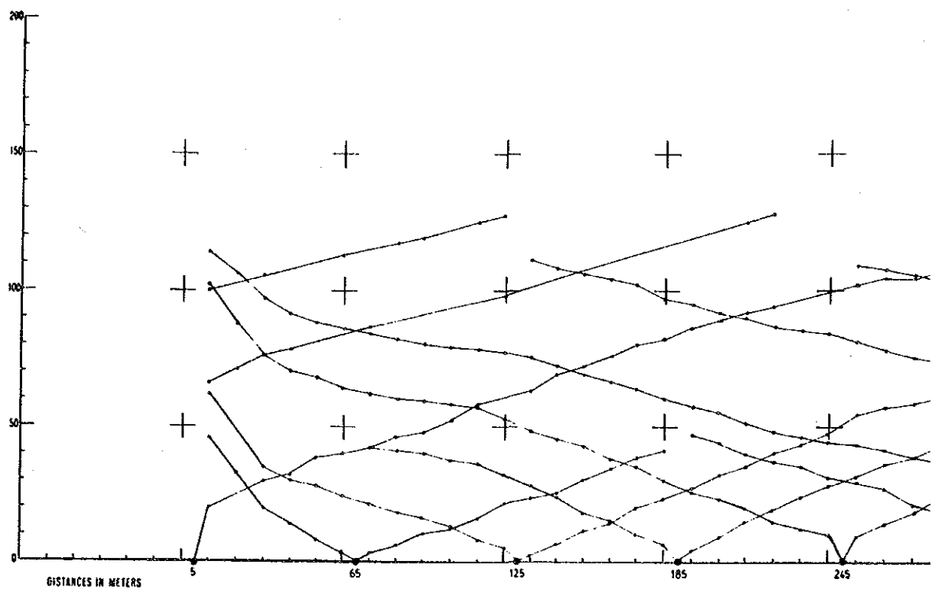
TAMBO
SEISMIC LI



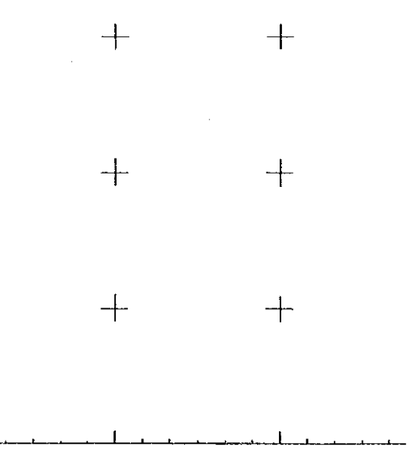
TIME-DISTANCE CURVES

TAMBO PUERTO PRADO
SEISMIC LINE : ST3



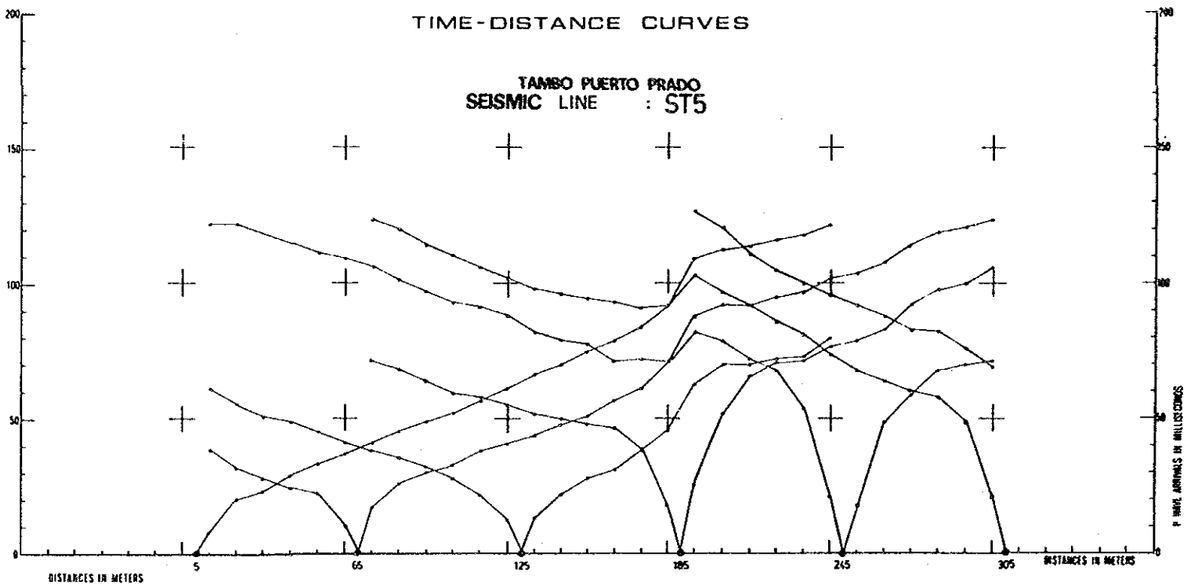


TIME-DISTANCE CURVES



TIME-DISTANCE CURVES

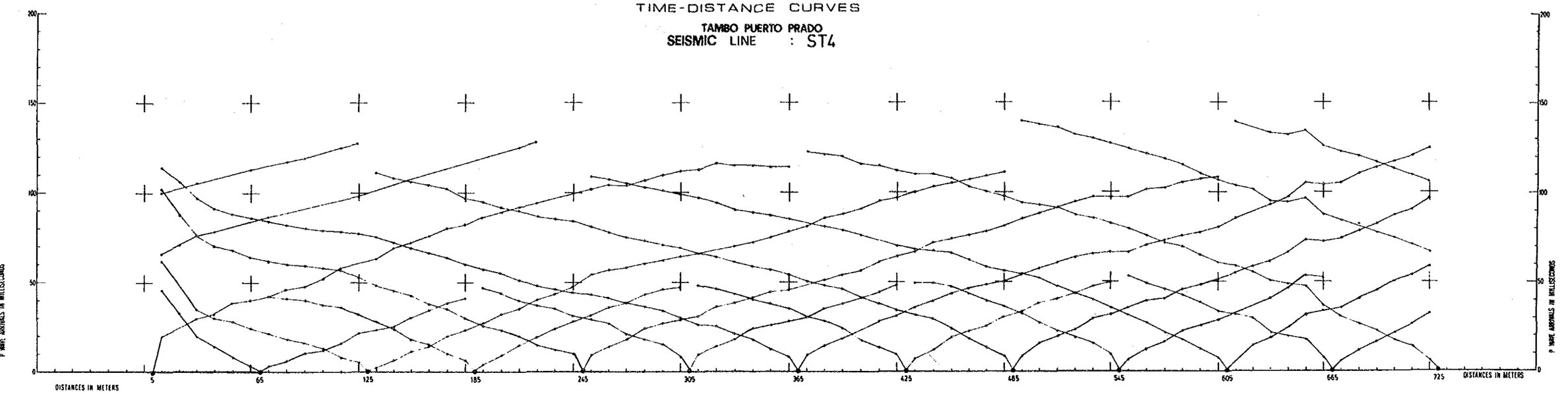
TAMBO PUERTO PRADO
SEISMIC LINE : ST5



TIME-DISTANCE CURVES

TAMBO PUERTO PRADO

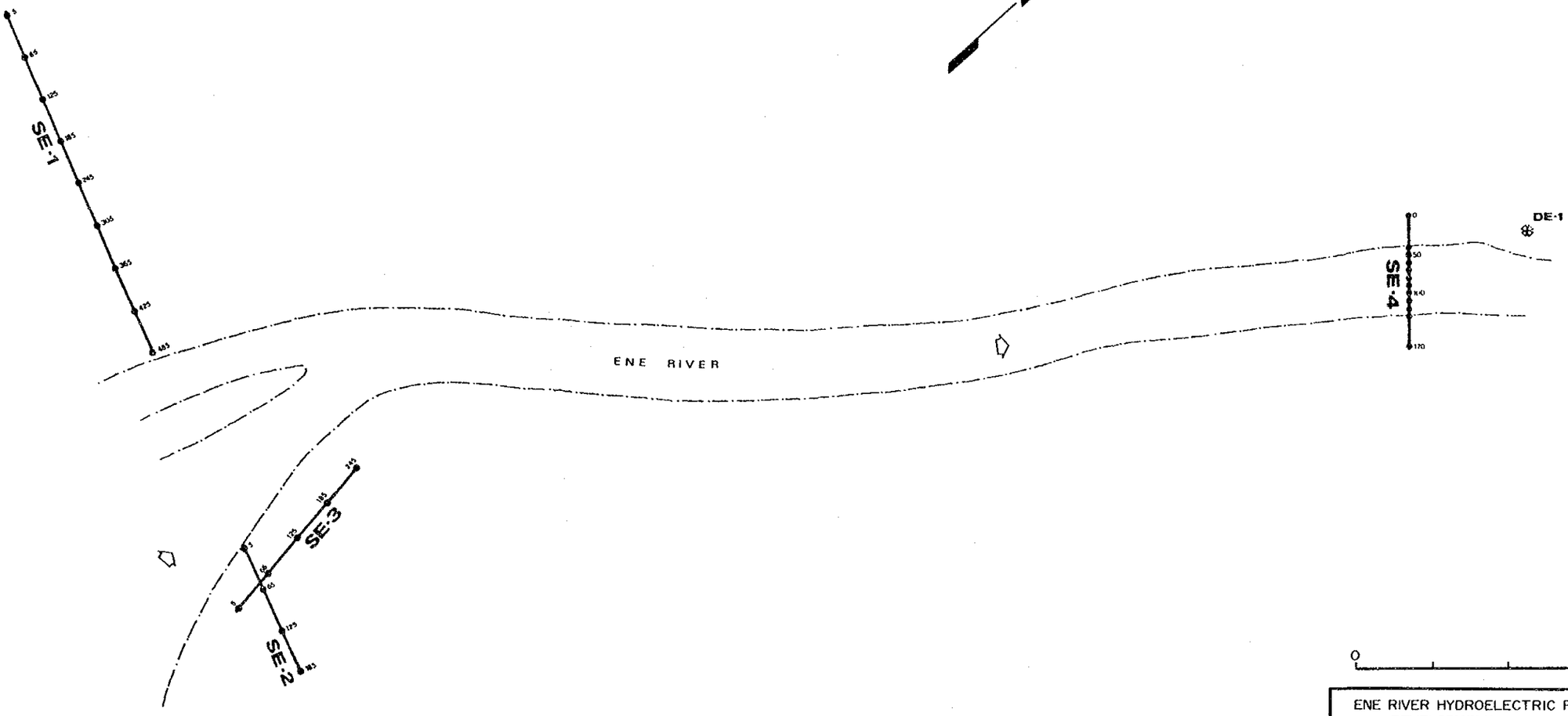
SEISMIC LINE : ST4



ENE RIVER HYDROELECTRIC POWER DEVELOPMENT PROJECT

SEISMIC PROSPECTING TIME-DISTANCE CURVES OF ST-3, ST-4, AND ST-5 LINES AT TAMBO PUERTO PRADO SITE

A-2 (10)
Sheet (3-5)



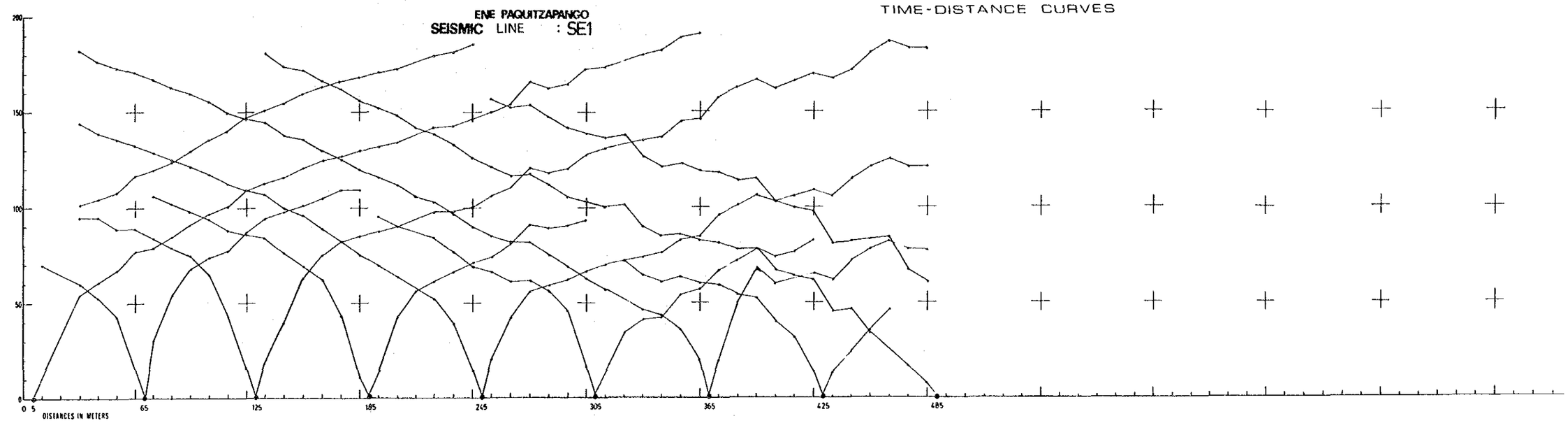
ENE RIVER HYDROELECTRIC POWER DEVELOPMENT PROJECT

SEISMIC PROSPECTING
LOCATION OF SEISMIC LINES
AT ENE PAQUITZAPANGO SITE

A-2 (10)
Sheet (4-5)

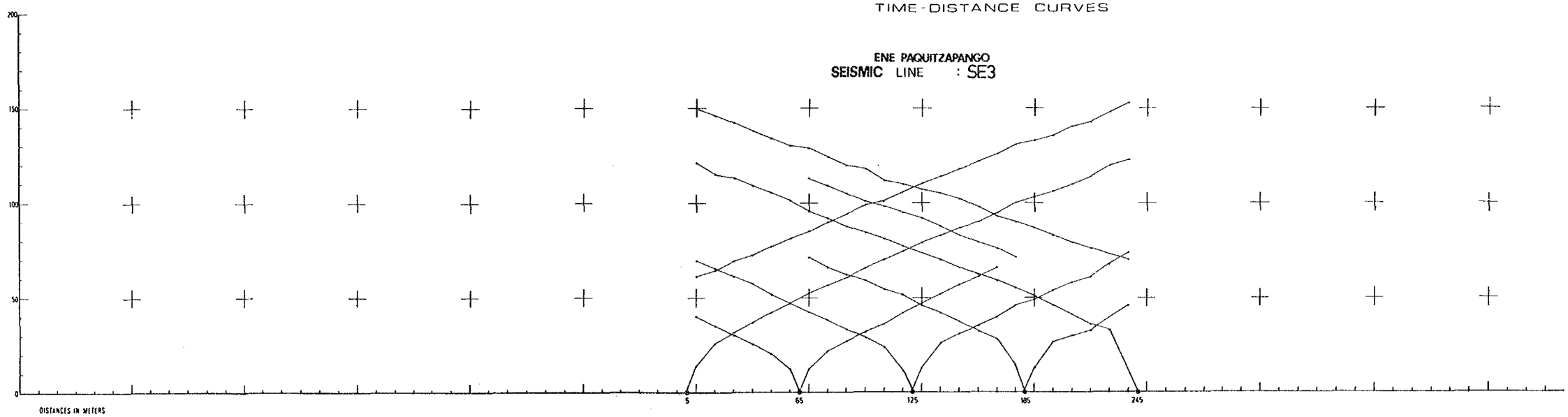
TIME-DISTANCE CURVES

ENE PAQUITZAPANGO
SEISMIC LINE : SE1

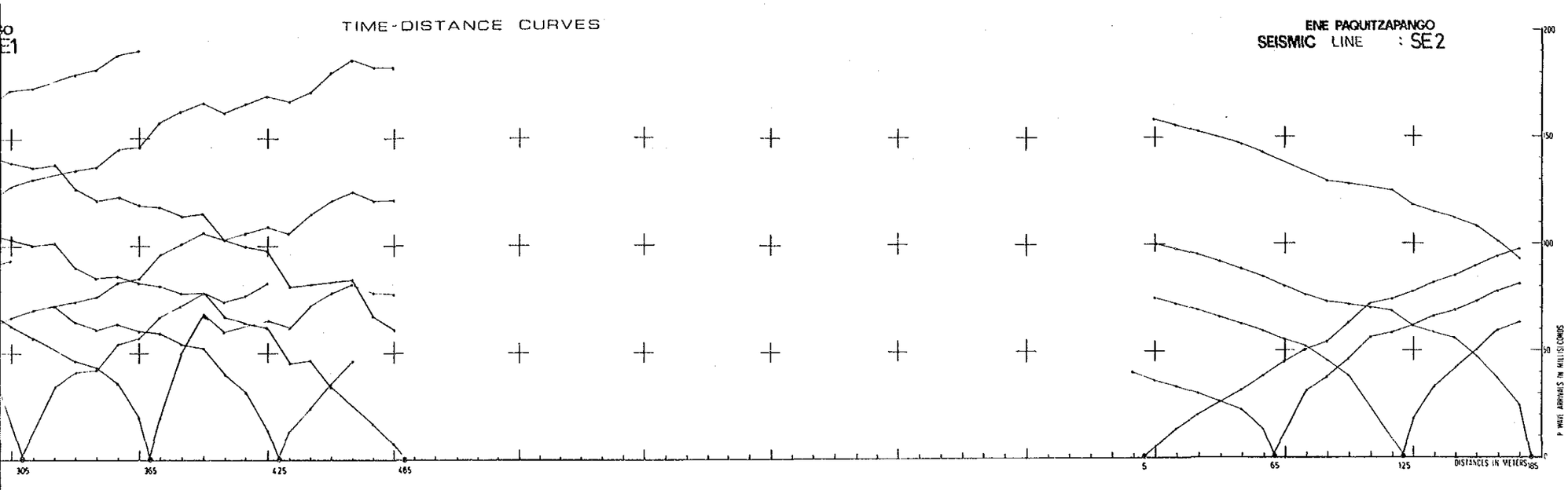


TIME-DISTANCE CURVES

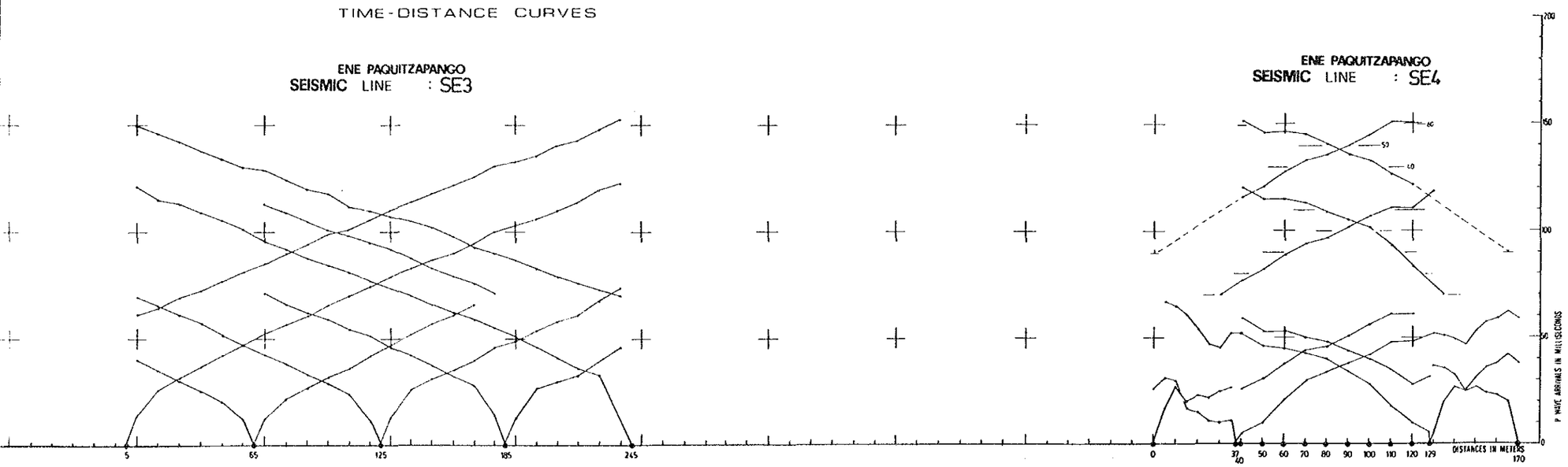
ENE PAQUITZAPANGO
SEISMIC LINE : SE3



TIME-DISTANCE CURVES



TIME-DISTANCE CURVES



ENE RIVER HYDROELECTRIC POWER DEVELOPMENT PROJECT

SEISMIC PROSPECTING
TIME-DISTANCE CURVES OF SE-1, SE-2, SE-3, AND SE-4 LINES AT ENE PAQUITZAPANGO SITE

A-2 (10)
Sheet (5-5)

(11) Outline of Landsat Image Analysis for Ene River Hydroelectric Power Development Project.

1. Objective of the Geological Survey

The objective of this survey is the investigation of geological structure of Ene River Hydro-electric Power Development Project area in the Republic of Peru. Within the project area, only area around the damsite and river is covered by aerial photographs. As for this area geological survey had been done by interpreting these photos and by using field survey results. Remaining area is large and not covered by aerial photographs. Therefore, for the geological survey of this remaining area, LANDSAT images were used. In interpreting Landsat images, results of geological survey of the area around damsite and river were used as keys. Final product of this geological survey using LANDSAT images is a geological map on a scale of 1:400,000.

2. The survey area

Subject area of this geological survey using LANDSAT images is shown in Fig.-1.

RELIEF DATA UNRELIABLE

Limits of reliable relief information

Image Processing Area

Row:068

Row:069

Path:005

1977.7.3

1978.8.12

1977.7.3

OPERATIONAL NAVIGATION CHART ONC N-25

Scale 1:1,000,000

Fig.1 Location map

3. Image Analysis

3.1 LANDSAT data used in the survey

LANDSAT scenes covering the subject area are Path:005/Row:068 and Path: 005/Row:069. Images of minimum cloud coverage and high quality were searched for these scenes. As for scene Path:005/Row:069 cloud free images was obtained from Brazil. However, as for Path:005/Row:068 the best images we could get were of 40 percent cloud coverage. In order to get a single cloud free image of scene Path:005/Row:068 by combining two images, which are partially covered by clouds, we purchased two images as shown on Table-1.

Table-1. LANDSAT data used in geological survey

Path - Row No.	date	cloud(%)	sun el., az.	note
005 - 068	JUL 03, 1977	40	33° , 52°	
005 - 068	AUG 12, 1978	40	42° , 57°	for interporation
005 - 069	JUL 03, 1977	0	32° , 51°	

3.2 LANDSAT color composite image

LANDSAT color composite image was produced in the following manner. Flow-chart of this process is as shown in Fig.-2.

(1) Pre-processing

As pre-processing of LANDSAT images, CCT conversion, reduction of noise in images, and geometric correction were done.

(2) Digital mosaic production

As for the scene Path:005/Row:068 two images were purchased from Brazil.

(i) The level of tone of 1978 image was adjusted to the level of tone of 1977 image. This process is called "normalization".

(ii) Parts of two images to be assembled to make a single cloud free image by mosaicing were determined as shown in Fig.-3.

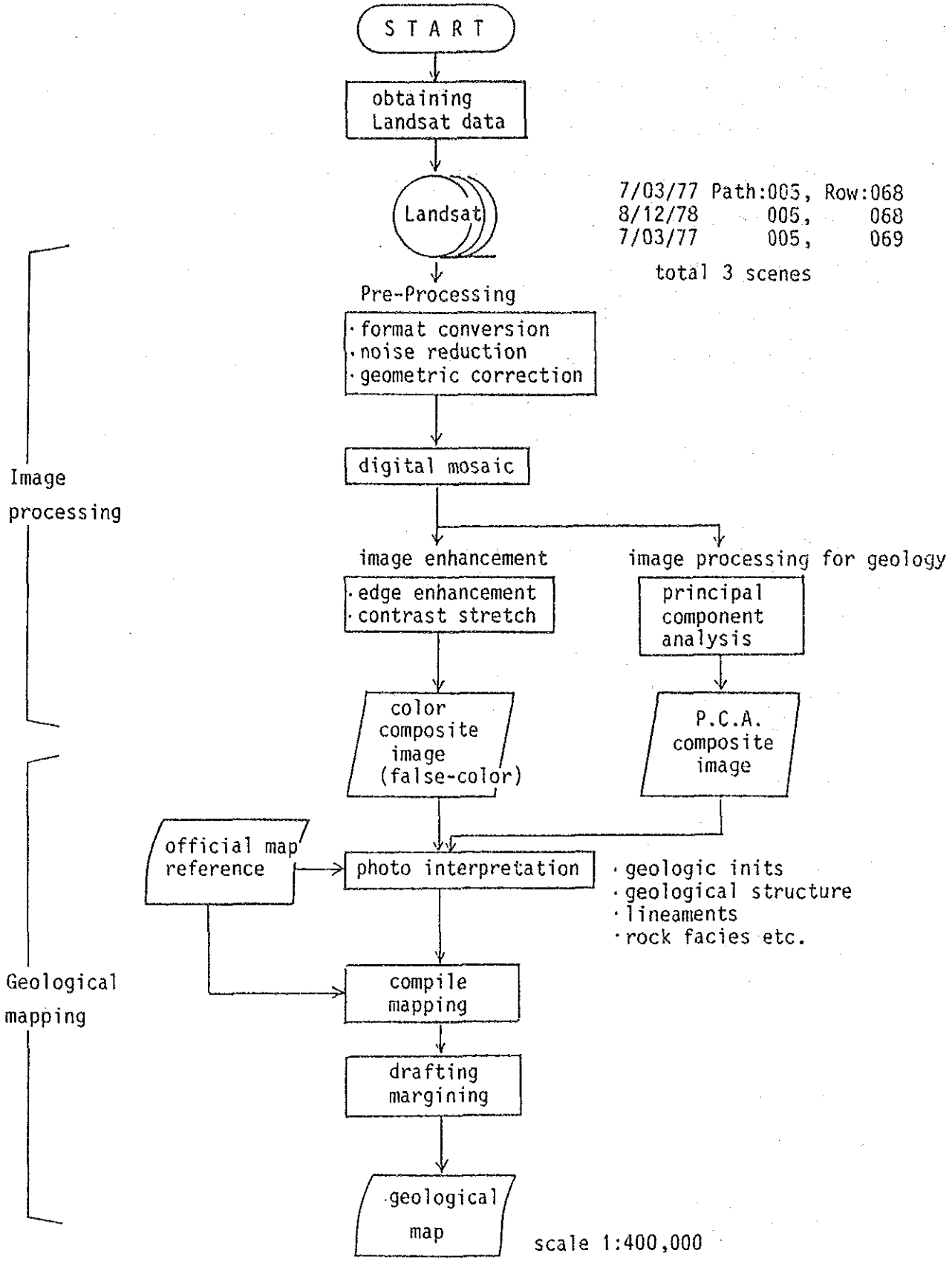


Fig.2 Flow-chart of geological interpretation from Landsat image

(iii) Geometric correction of 1978 image was done by using 1977 image as basic data.

(iv) Mosaicing of two images - more precisely, parts of two images - was done digitally.

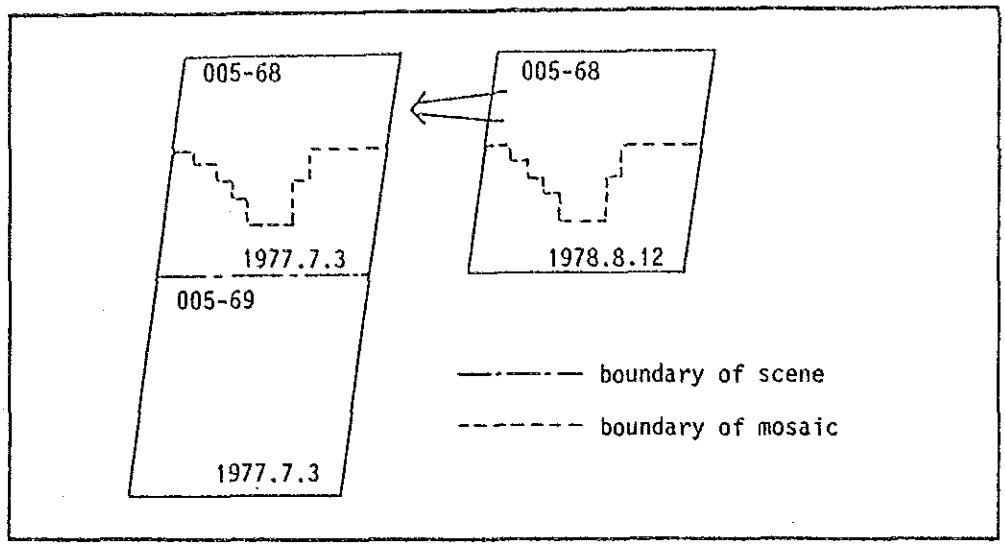


Fig.-3. The illustration of digital mosaic processing

(3) Image enhancement

To make geological interpretation easy, edge-enhancement and contrast stretching were done. After image enhancement, color composite image was produced by using photo-printer. This color composite image was enlarged to a scale of 1:250,000 and used in geological interpretation of LANDSAT image Fig.-4 is the LANDSAT color composite image used in this survey at original scale of 1:1,000,000.

Fig. 4 False-color composite image
(digital mosaic and edge-enhancement)

Scale 1:1,000,000

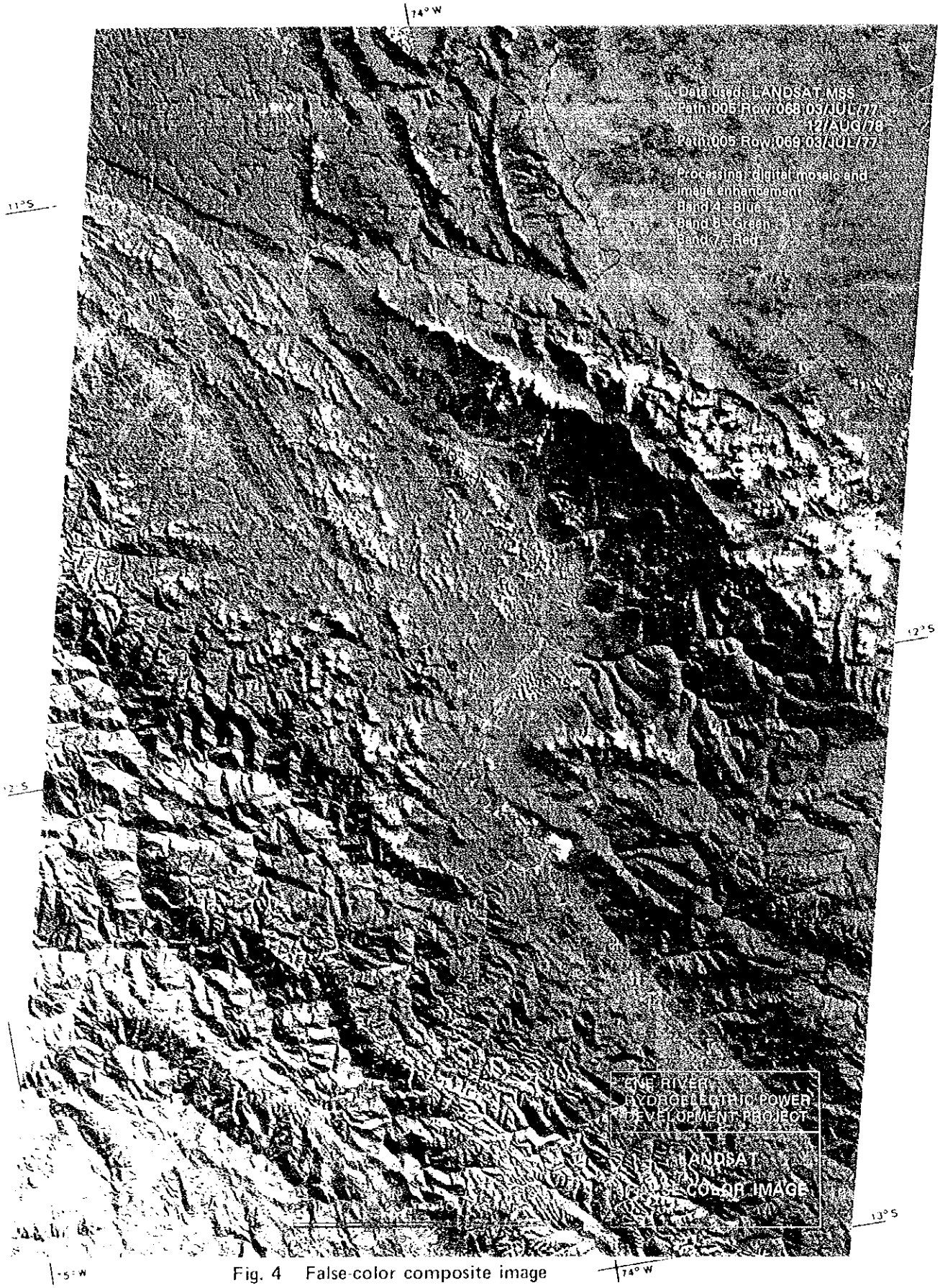


Fig. 4 False-color composite image
(digital mosaic and edge-enhancement)

Scale 1:1,000,000

3.3 Image processing for geological and geographical surveys

Image processing is often effective, when large amount of information on geological features need to be supplied to interpreter. In this survey, principal component analysis (P.C.A.) was used as a image processing method.

The principal component analysis is a method that uses four spectral bands of LANDSAT data. Eigenvalue of from first component to third component is computed, and then, using these eigenvalue, each component score is computed. The output is composite using Munsell color solid system shown in Fig.-5. Fig.-6 is a composite image in which the first component is assinged to intensity, the second to hue, and the third to saturation.

From this composite image, the following thing is understood:
Reflectance on the ground is expressed as the first component (difference of intensity). Vegetation density is expressed as the second component (difference of hue).

In this way, amount if information to be supplied to interpreters is greater than the case that information source is only color composite image.

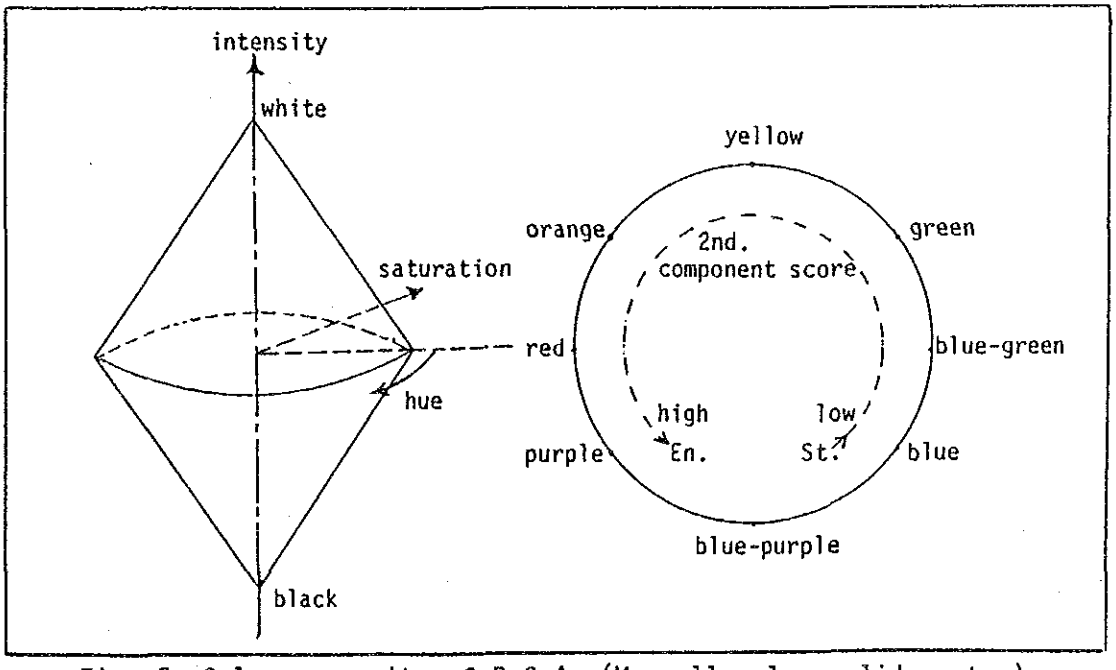


Fig.-5 Color composite of P.C.A. (Munsell color solid system)

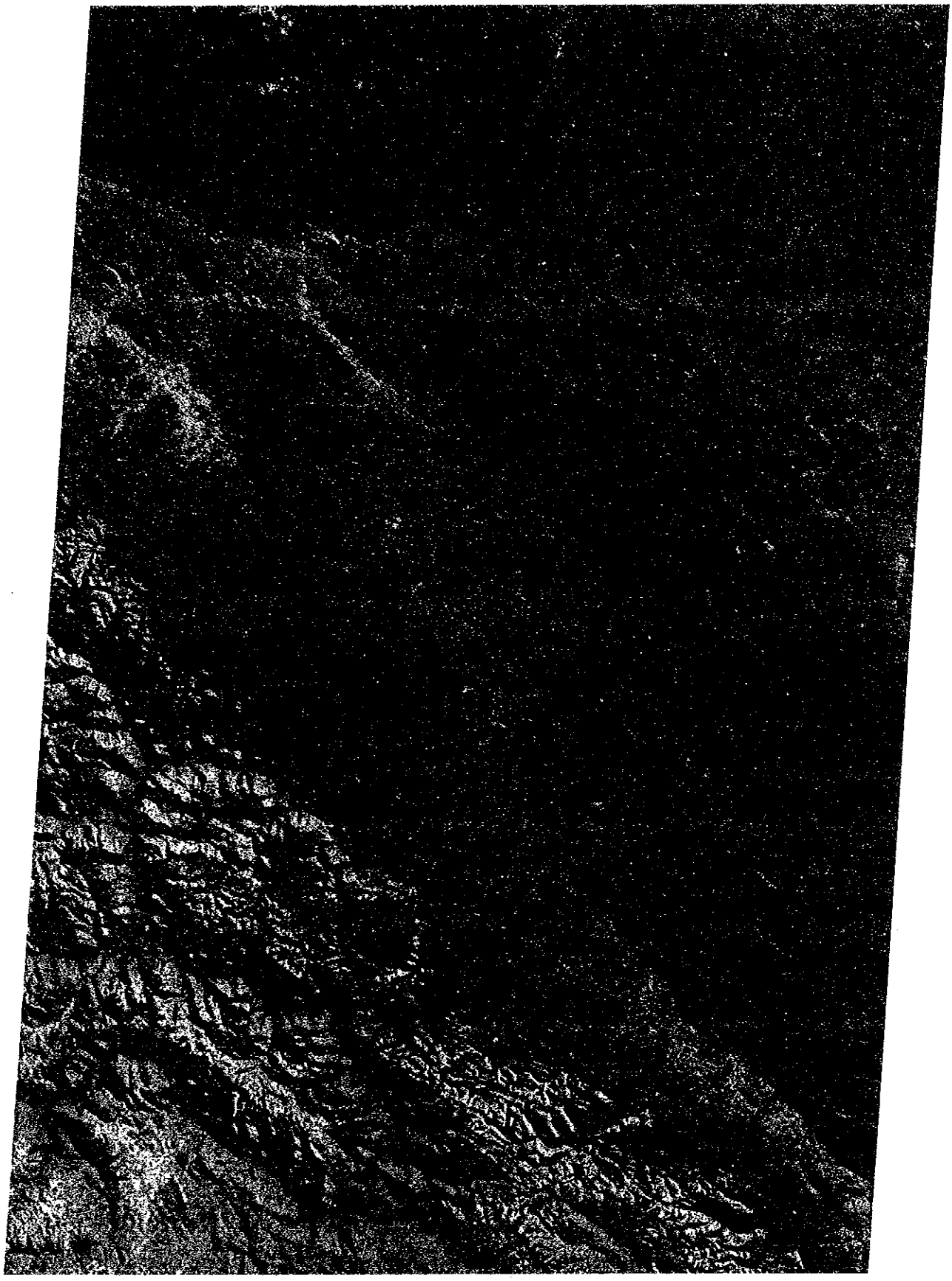


Fig. 6 Principal Component Analysis; P.C.A. composite image

1st component ---- Intensity
2nd component ---- Hue
3rd component ---- Saturation

Scale 1:1,000,000

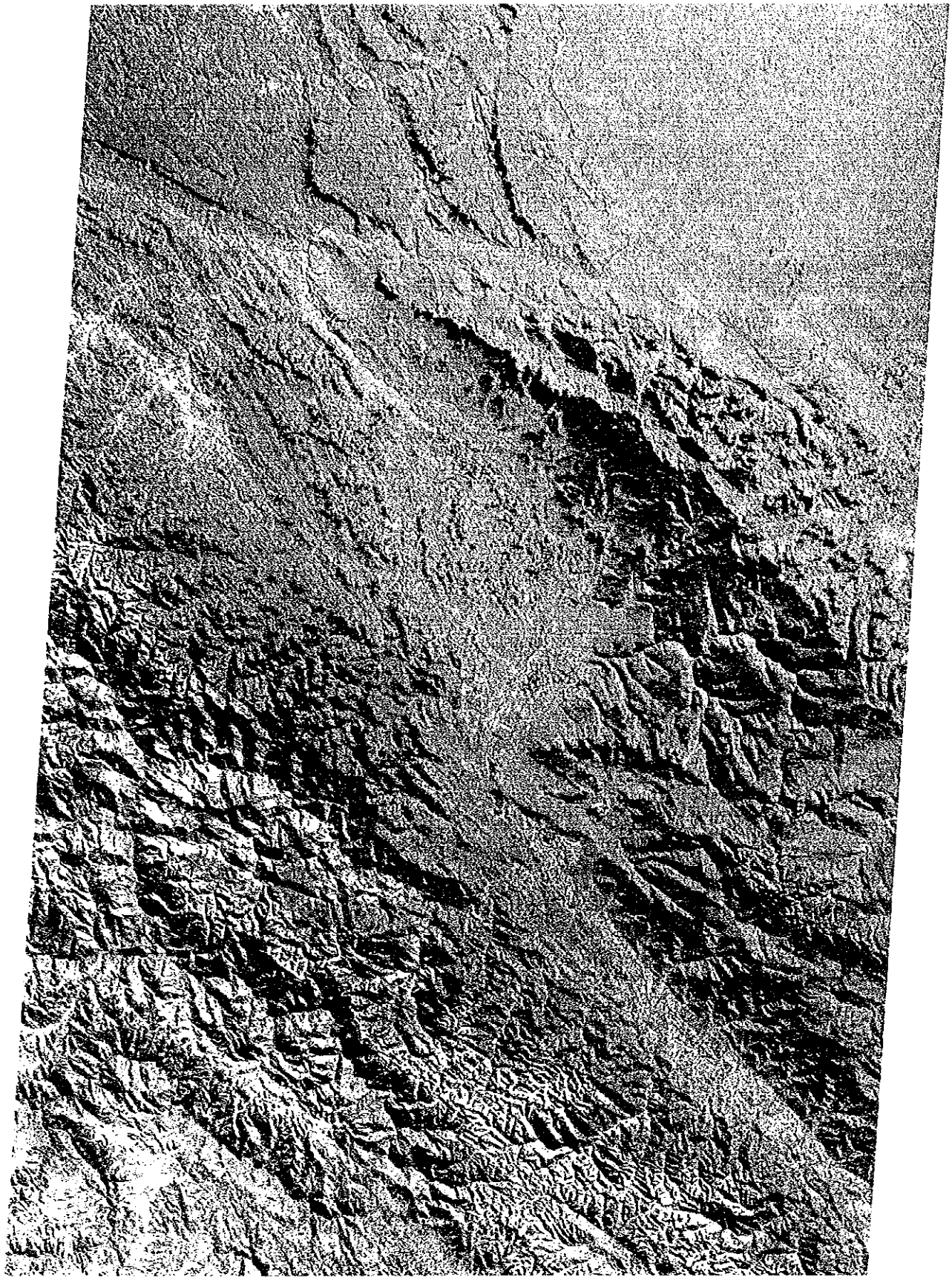


Fig. 6 Principal Component Analysis; P.C.A. composite image

1st component —·— Intensity
2nd component —·— Hue
3rd component —·— Saturation

Scale 1:1,000,000